DEVELOPMENT OF A DECISION SUPPORT GEOGRAPHIC INFORMATION SYSTEM FOR LAND RESTORATION PROGRAMS IN THE LEON, LAMPASAS, AND BOSQUE RIVER WATERSHEDS

A Thesis

by

JASON SAMUEL JONES

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Rangeland Ecology and Management

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Approved by:

Chair of Committee,	J. Richard Conner
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May 2006

Major Subject: Rangeland Ecology and Management

ABSTRACT

Development of a Decision Support Geographic Information System for Land Restoration Programs in the Leon, Lampasas, and Bosque River Watersheds. (May 2006)

Jason Samuel Jones, B.S., Texas A&M University

Chair of Advisory Committee: Dr. J. Richard Conner

Ashe Juniper encroachment onto privately owned rangelands in Central Texas has resulted in significant degradation of the ecological condition of these lands, and a subsequent public concern for the hydrologic function, wildlife habitat, and livestock production these historically predominant grasslands provide. The result has been an interest and public investment in land restoration programs such as the removal and management of brush via landowner cost-share. Implementation of a publicly funded land restoration program requires the allocation of millions of dollars of public funds on private lands over large geographic areas that represent hundreds of landowners with varying property management objectives, tract sizes, ecological conditions, and geologic characteristics.

This study describes the development, accuracy, and application of a decision support geographic information system (DSGIS) for land restoration programs in the Leon, Lampasas, and Bosque River watersheds in the Brazos River basin of Central Texas. The spatially referenced data layers and associated database within the DSGIS provide the capability to assemble site specific information including vegetation cover, endangered species habitat, landowners, ecological sites, elevation and slope,

hydrologic characteristics, and political boundaries to support policy and implementation decisions for Ashe Juniper (*Juniperus ashei*) brush control and management and golden-cheeked warbler (*Dendroica chrysoparia*) habitat restoration programs. The golden-cheeked warbler is a federally listed endangered species with a breeding range limited to the oak-juniper woodlands of Central Texas. The data layers were developed with the support of ongoing research from the Leon River Restoration Project (LRRP) in Coryell and Hamilton counties.

One hundred and eighty-eight (188) sub-watersheds were delineated within the project area and prioritized for implementation of an Ashe Juniper brush control program and a golden-cheeked warbler habitat restoration program. Costs associated with the clearing and stacking of Ashe Juniper were estimated for selected sub-watersheds based on projected landowner participation and an analysis of actual costs from the LRRP. Sub-watersheds were targeted for the implementation of an Ashe Juniper brush control and golden-cheeked warbler habitat management program in Bosque, Coryell, Lampasas, Bell, and Burnet counties. Detailed tables were also developed to document the density and quantity of pertinent layer attributes within each of the 188 sub-watersheds.

DEDICATION

This thesis is dedicated to the generations of landowners and conservationists who have come before us and have committed their lives to the delicate balance between productive agriculture and the preservation of our natural resources for the generations that lie ahead. May each of us recognize and continue to improve upon their efforts.

ACKNOWLEDGMENTS

I would first like to thank my graduate committee members for their invaluable support and contributions throughout the conception, development, and completion of this project. Thank you Dr. Conner, for your timely reviews, patience, and input throughout all the submittals, revisions, and paths this project has led us down. Thank you Mr. Hamilton for your insight, wisdom, and guidance, and thank you Dr. Wilkins for your perspectives, input, and critique that has continually challenged my intuition and added value to the final product.

Without the efforts and success of the Leon River Restoration Project team, this project would surely not have been possible. Mr. Steve Manning, your continued foresight and leadership of this dynamic team deserve the utmost recognition. The Texas A&M University faculty and graduate students have also made tireless contributions to this project. Specifically, I would like to recognize the contributions of the Phase I Research team: Edwin Juarez and Tiffany Cummins for the bird survey work; Dr. Smeins, Frank Holland, and Tim Brown for the vegetation survey efforts; Dr. Knight, Courtney Hale, and Lisa James for their watershed research; and Jenny Sanders for the perspectives on landowner characteristics.

My parents, Sam and Margaret Jones, have been a continuous support, a blessing, and a cornerstone in my life. I would finally like to thank my beautiful wife, Charlotte, for her continued love and support throughout my graduate career and beyond.

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CHAPTER I

INTRODUCTION

This study describes the development of a decision support geographic information system (DSGIS) designed to support policy and implementation decisions for private property land restoration programs in Central Texas areas where Ashe Juniper (*Juniperus ashei)* encroachment is a public concern. The DSGIS is a compilation of geographically referenced data layers, each representing either a natural resource variable or a political boundary important for large scale land restoration projects related to Ashe Juniper control and management. The study area for the DSGIS is within the Central Texas portion of the Brazos River basin and includes the contributing watershed boundaries for the Lampasas, Leon, and Bosque Rivers (Fig. 1).

The data layers that have been developed for the DSGIS are based largely on research conducted under the Leon River Restoration Project (LRRP). The LRRP is an ongoing research scale brush control project within the Leon River watershed in Hamilton and Coryell Counties. The research objectives of the LRRP are to quantify the impacts of Ashe Juniper removal and management on rangeland water yield, endangered species habitat including the federally listed golden-cheeked warbler (*Dendroica chrysoparia)* and black-capped vireo (*Vireo atricapillus)*, and forage production for livestock (Hamilton, 2004). The research objectives of the DSGIS could not have been accomplished without the parallel contributions of the LRRP.

This thesis follows the style of *Rangeland Ecology and Management*.

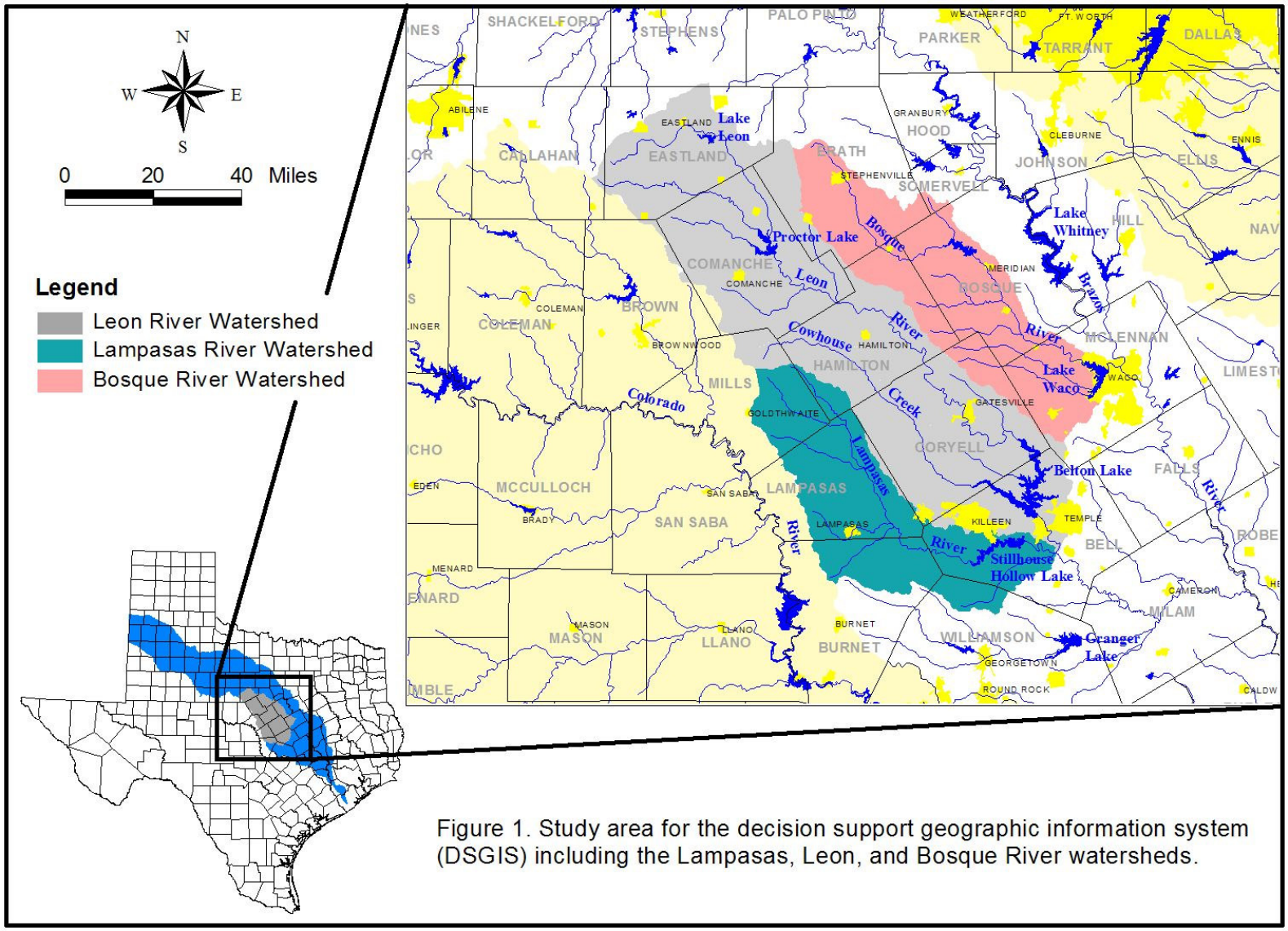

Figure 1. Study area for the decision support geographic information system (DSGIS) including the Lampasas, Leon, and Bosque River watersheds.

Problem Statement

The concept of the DSGIS was initiated with the recent implementation of a program in Texas for partially funding brush control work on private lands with public money. These brush control programs target the removal and management of brush species on private property through landowner cost-share programs. The cost-share programs typically fund 50-85 percent of the landowner's cost to treat the brush and provide additional incentives for follow-up management practices (i.e. deferred grazing and controlled burns). The brush control programs are funded and driven by a public desire to enhance the potential for increased water yield, improved water quality, improved wildlife habitat, and increased grazing for livestock enterprises on privately owned upstream rangeland watersheds.

Implementation of a publicly funded land restoration program requires the allocation of millions of dollars of public funds on private lands over large geographic areas. The large geographic areas represent hundreds of landowners with varying property management objectives, tract sizes, ecological conditions, and geologic characteristics. These variables all add to the complexity and level of knowledge required to efficiently and effectively manage a land restoration program. This detailed level of information is not widely available at the present time.

Objectives

The goal of this research is to develop a DSGIS for land restoration programs in the Leon, Lampasas, and Bosque river watersheds. The following are specific objectives of the research:

1. Apply the ongoing research efforts and conclusions of the LRRP that have been conducted within the Leon River watershed of Hamilton and Coryell Counties to the surrounding watersheds of the Leon, Lampasas, and Bosque Rivers.
2. Assemble readily available geographic data within the study area into a geographic information system. Available data layers include ecological sites, a digital elevation model, streams and rivers, county and urban boundaries, and roads.
3. Develop vegetation, golden-cheeked warbler habitat potential, and landowner property boundary data layers of the study area. Analyze the accuracy of the vegetation map and the golden-cheeked warbler habitat model based on data collected as part of the LRRP.
4. Provide an analysis of the treatment costs, specifically the mechanical removal of Ashe Juniper, associated with the LRRP as well as the expected level of landowner participation based on available research. Evaluate the alternatives for predicting the cost and participation level of a similar type of land restoration project implemented within the study area.
5. Prioritize and target specific counties, sub-watersheds, or individual landowner tracts within the study area for implementation of land restoration practices based on the density and location of juniper, golden-cheeked warbler habitat, landowner tract size, and percentage of privately owned rangeland.

Thesis Organization

The remainder of the thesis is organized into four Chapters and a supporting Appendix. Chapter II provides a review of the literature and supporting information for the research. Chapter III presents a detailed methodology for the research. Chapter IV includes a detailed summary and discussion of the accuracy, pertinent data, and results of the DSGIS, and Chapter V provides a summary, conclusions, and recommendations for future research.

CHAPTER II

LITERATURE REVIEW

The following sections provide a discussion of the motive, impacts, and existing planning efforts for publicly funded land restoration efforts. To date, major land restoration programs in Texas have been focused on the encroachment of brush species onto historically predominant grasslands, with the primary objective of removing the brush to enhance offsite water yield. Increasing attention also has been given to the potential for linking these types of brush control programs to the restoration of habitat on privately owned rangelands for endangered bird species including the black-capped vireo and golden-cheeked warbler. A review of the research on the potential benefits of brush control projects including rangeland water yield, wildlife habitat, and landowner economics is followed by a discussion of the planning efforts for existing brush control projects as well as landowner participation research for these types of programs. Finally, the concept of decision support systems and geographic information systems is introduced along with examples of similar types of systems currently used to support natural resource management efforts.

Publicly Funded Brush Control for Increased Water Yield

The Texas Legislature has had a history of interest in brush control since 1985, when the Texas Brush Control Program was created under the management of the Texas State Soil and Water Conservation Board (TSSWCB). Public funding has been available for brush control beginning in Fiscal Year 2000, with an appropriation of over $9,000,000 within the North Concho River watershed. A total of $37,000,000 has since been appropriated

for brush control work within selected watersheds between Fiscal Years 2000 and 2005 (TSSWCB 2004).

Three concurrent issues have influenced and driven public funding for brush control projects as well as research on the ecological and hydrologic impacts of brush on semiarid rangelands in the State of Texas over the past 20 years. They include an increase in human populations and accompanying water demands in these regions, the widespread encroachment of shrubs on historically predominant grasslands, and multiple accounts of the decline in historically perennial springs and upland streams across Central and West Texas.

The population of Texas is expected to almost double, from 21 million people in 2000 to about 40 million in 2050 (TWDB 2002). In addition, by 2050, almost 900 cities (38% of the projected population) will not have adequate water supplies, which amounts to a projected shortage of 7.5 million acre-feet per year. Current regulations on inter-basin transfers are also increasing the reliance on groundwater resources and placing higher demands on existing surface water resources within water short basins in the Western portions of the State. Conservation is recognized as a very critical element to meet the States' long-term water needs, and brush management is recognized as an innovative new strategy to mitigate the projected increase in water demands other than building new lakes or drilling new wells (TWDB 2002).

The encroachment of shrubs within semiarid landscapes of the Southwest United States is well documented (Archer, 1994). Smeins et al. (1997) indicated that relatively frequent wildfires and the lack of continuous livestock grazing likely maintained open

grasslands over much of Central Texas prior to European settlement. The reasons for the vegetation change across much of the Southwestern rangelands can largely be attributed to anthropogenic activities. Hamilton and Ueckert (2000) summarized the influence of man's activities on rangeland vegetation change by the following factors:

1. Continual and excessive grazing pressure on grasslands by an increase in the number of grazing animals.
2. Reduction of naturally occurring fires.
3. Intentional and severe restrictions in the movements of grazing animals by fencing.
4. Cultivation and abandonment of grassland soils.
5. Increased mobility of man and his animals which augmented the dispersion of woody plant propagules.
6. Introduction of woody plants which have escaped cultivation to become serious problems.
7. Increase in competitive advantage to woody plants over warm-season perennial grasses associated with the elevation of atmospheric carbon dioxide.

Many of the flowing springs and beautiful streams that Texas has become known for are being depleted at an alarming rate. Brune (2002) spent a decade of the latter part of his life documenting historically perennial springs across 183 of the 254 Texas counties that were declining in flow rate or that no longer flowed as of the mid 1970's. He attributed the major cause of the declining springs to over-pumping of groundwater resources for irrigation and municipal use, as well as the impacts that a century of

overgrazing, soil compaction, and brush invasion have had on aquifer recharge rates. The negative impact of brush invasion on the water cycle has been documented by other anecdotal evidence, including the story of Rocky Creek. Rocky Creek is a 20-mile long stream located Northwest of San Angelo, Texas that flows into the Middle Concho River and had dried up during the 1930's drought (Kelton 1975). The stream began flowing again due to the recovery of dozens of perennial seeps and springs in the 1960's following brush control on about 35,000 acres within the 74,000 acre watershed. The brush control was coupled with a carefully planned grazing system that allowed the perennial grasses to recover. Kelton also wrote of a similar example on nearby Tepee Draw, which also flows into the Middle Concho River. Additional anecdotal evidence is included in a brush control feasibility study that was published by The Upper Colorado River Authority in 1998 for the North Concho River Watershed. The hydrology and ecology of the region from the early nineteenth century through 1950 was analyzed from historical documents and interviews with local residents. Multiple accounts of perennial springs, streams that "flowed all the time," and streams with deep pools where children fished and swam in the summers prior to 1950 were recorded. After the drought of the 1950's, many of the perennial springs and streams dried up and never returned. The dramatic hydrologic change has been coupled with an increasing rate of mesquite and juniper encroachment into the upland areas of the watershed (UCRA 1998).

Current State of the Research on the Impacts of Shrub Encroachment

Rangeland Water Yield. The increasing water demands in the State coupled with a decline of historically perennial springs and increase in brush cover has spurred research on the impacts of shrubs on the water cycle in Texas for over a decade. Although most of the research is limited to plot, local, and hillslope scales, the evidence is encouraging given the right combination of vegetation, geologic, and climatic factors.

Steffens and Wright (1996) demonstrated that a perennial seep spring on the headwaters of Little Seco Creek in Uvalde County, Texas showed an increase in flow for 4 years following hand removal of 7.9 acres of regrowth Ashe juniper up slope of the spring. The spring flow increased from an average of 14% of the annual water budget to 25% of the annual water budget. In addition, pretreatment monitoring results of four spring sites with heavy Ashe juniper cover up slope in Coryell County, Texas indicate a cyclic flow variation during a 24 hour period, likely related to higher transpiration rates of the vegetation during daytime hours (James et al. 2004).

Evapotranspiration rates and runoff were monitored on a treated and untreated paired watershed within the Seco Creek watershed by Dugas et al. (1998). During the first two years following treatment, the untreated site showed higher evapotranspiration rates and higher water use than the treated site, indicating the potential to increase aquifer recharge following juniper clearing. However, the difference in evapotranspiration was negligible after 2 years due to a flush of herbaceous growth on the treated site. Nonetheless, runoff results indicated a much lower runoff rate from the treated site during the third year following treatment once the herbaceous vegetation was

established, which has the potential for increased aquifer recharge due to a decrease in runoff. Owens and Lyons (2004) determined that Ashe juniper trees in the Edwards Plateau of Central Texas physically intercepted nearly 40% of the ambient rainfall over a three year period. This intercepted rainfall never made it to the soil surface beneath juniper trees across a broad geographic region.

Carlson et al. (1990) demonstrated a decrease in runoff and soil erosion and an increase in evapotranspiration following the clearing and herbaceous recovery of a mesquite plot near Throckmorton, Texas. The deep drainage on the herbaceous plot increased by 0.6% over a three year period likely due to the decrease in runoff. Although brush removal may not impact evapotranspiration rates on some sites due to a flush of herbaceous vegetation, it is well recognized that established perennial grasslands (i.e., native bunchgrass) serve the hydrologic function of decreased erosion, higher infiltration, and the potential for higher aquifer recharge rates than overgrazed or shrub dominated rangelands.

Wilcox et al. (2006) have documented our current state of knowledge regarding the role of shrubs on runoff processes from rangelands at the local, catchment, and landscape scale. A shrub-streamflow framework was utilized to identify specific physiographic and climate settings that have the potential for hydrologically sensitive shrublands. It was concluded that for semiarid, upland shrublands to be hydrologically sensitive to changes to woody plant cover, soil water or groundwater must be at a depth available to deep-rooting shrublands, but too deep for shallow-rooting grasslands. These types of upland shrubland environments have a potential water savings of 40-80 mm/yr

when the deep-rooting shrubs are removed and replaced with grasslands. Most semiarid shrublands in Texas are not hydrologically sensitive due to the presence of deep soils that retain annual precipitation volumes in the upper one meter of soil. However, Ashe juniper-dominated rangelands in Central Texas do have the potential to increase runoff as shrub cover decreases due to the presence of karst limestone geology, subsurface flow, and the dual effect of interception and transpiration loss of the juniper (Wilcox 2004).

Wildlife Habitat. The primary public driver for brush control funding has historically been concerns for water yield; however, endangered species habitat restoration has become a well recognized benefit and consideration in the planning and implementation of recent brush control programs, specifically the Leon River Restoration Project (LRRP). A primary objective of the LRRP is to quantify the impacts of Ashe juniper removal and management on wildlife habitat for the federally listed black-capped vireo and golden-cheeked warbler, and to incorporate long term management practices to maintain wildlife improvements (Hamilton 2004). It is well documented that native brush species are a key wildlife habitat component; however, vast, dense stands of brush are not conducive to wildlife habitat (Rollins and Cearley 2004).

The golden-cheeked warbler is a federally listed endangered species with a breeding range limited to the Edwards Plateau of Texas (Ladd and Grass 1999). The black-capped vireo also is a federally listed endangered species, and its core population is found in the Edwards Plateau of Texas (Hayden et al. 2000). The golden-cheeked

warbler has very specific habitat requirements, such as the use of bark from mature Ashe Juniper trees for building nests. Prime nesting habitat for golden-cheeked warblers includes stands of mature Ashe Juniper mixed with deciduous hardwoods along streams and canyons in the eastern part of the Edwards Plateau (USFWS 1992). The black-capped vireo, on the other hand, does not require Ashe Juniper for its habitat and prefers a variety of low-growing deciduous shrubs including shineoak (*Quercus* spp.), Texas persimmon (*Diospyros texana*), and sumacs (*Rhus* spp.) (Grzybowski 1991, as cited in Rollins and Armstrong 1997). The management of rangelands to include an open mosaic of juniper patches and open shrublands will likely help maintain the habitat requirement of these endangered bird species (Juarez 2004). While both of these species are a concern for restoration programs in Central Texas, management strategies for the endangered golden-cheeked warbler are the primary focus of this research. The habitat requirements and recovery needs are more conducive to the mapping tools used in the DSGIS (Chapter III).

The destruction of the golden-cheeked warbler is mostly attributed to habitat fragmentation and destruction from urbanization and agricultural practices. Other forms of habitat and species loss include high rates of brown-headed cowbird (*Molothrus ater*) brood parasitism, destruction of oak and deciduous species due to oak wilt and over-browsing by white-tail deer and goats, and proximity to urban areas leading to increased risks from nest predators such as blue jays (*Cyanocitta cristata*) (USFWS 1992). Pulich (1976) found eggs of cowbirds in 19 of 33 (58%) golden-cheeked warbler nests (as cited in USFWS 1992). Brown-headed cowbird parasitism is also a threat to black-capped

vireo populations, as 90.9% of all vireo nests at Fort Hood were parasitized in 1987 (Hayden et al. 2000). The brown-headed cowbird historically occupied short-grass prairies, and followed migrating buffalo herds to feed on insects stirred up by the movement and grazing of these herds. Several anthropogenic factors have increased the density and habitat range of the brown-headed cowbird, including urbanization and livestock overgrazing (USFWS 1992). Encroaching stands of juniper typically encourage the overgrazing of remaining grassland areas by livestock and wildlife herbivores. These overgrazed areas are beneficial for the brown-headed cowbird, which feeds on insects exposed by overgrazing and soil disturbance (Gill Eckrich, personal communication 2003). Brown-headed cowbird control programs including shooting and trapping have been in effect since 1988 on Fort Hood (Hayden et al. 2000) and have virtually eliminated the threat of brood parasitism on the military installation. A steady increase in golden-cheeked warbler populations on Fort Hood during a 10-year period between 1992 and 2001 is attributed to habitat protection and implementation of a cowbird control program (Anders and Dearborn 2004).

The U.S. Fish and Wildlife Service golden-cheeked warbler recovery plan has identified a list of actions needed for the recovery of the species, which includes the enhancement and maintenance of the quality of habitat on public and private lands (USFWS 1992). Management efforts on these lands include cowbird control programs and management of deer populations and livestock herds to reduce the impact on regenerating deciduous oak species. The process of identifying potential habitat on privately owned lands should consider a minimum habitat size required for golden-

cheeked warblers. Territory sizes for the golden-cheeked warbler averaged 4.15 hectares per breeding pair between 1992 and 1996 at Fort Hood (Ladd and Grass 1999). The U.S. Fish and Wildlife Service Recovery Plan referenced the available studies in 1992 regarding population density, which included a density of between 9.5 and 20 pairs per 40 hectares (USFWS 1992). However, the minimum patch size for the golden-cheeked warbler is likely several times greater than the average territory size, as golden-cheeked warblers in Travis county tended to choose sites larger than 100 hectares (Coldren 1998). Arnold et al. (1996) concluded that the golden-cheeked warbler required a minimum patch size of 23 hectares. The U.S. Fish and Wildlife Service recommended that patch sizes less than 50 hectares should be included in the management of golden-cheeked warblers, because thirty-four percent (36/107) of patches of habitat smaller than 50 hectares were inhabited by golden-cheeked warblers (Benson 1990, as cited in USFWS 1992). The Texas Department of Agriculture recently formed a committee to develop specific criteria for the conservation and management of golden-cheeked warbler habitat on privately owned lands. Preliminary results of the committee concluded that the minimum size criteria for a conservation unit should be at least 20 hectares (50 acres) within a single privately owned property and must be part of a block of at least 100 hectares (250 acres) of continuous golden-cheeked warbler habitat (Texas Department of Agriculture, Species Biology and Habitat Management Committee Recommendations, unpublished data). Consideration is also given to the proximity of the privately owned habitat to an existing Recovery Region (i.e., State or Federally

owned and protected habitat). Identification of these lands is an important step in the recovery process for the golden-cheeked warbler.

Landowner Economics. Brush management practices are commonly employed on Texas rangelands to enhance livestock production via increased forage production and enhance their suitability for wildlife habitat and associated hunting enterprises (Conner 2004). The economic value of increased forage production following brush treatment practices is difficult to quantify, as it is influenced by many factors including effectiveness of the brush treatment, soil type, vegetative production potential, grazing management, and climate (Olenick 2002). Jones and Conner (2004) concluded that the average annual value of economic enterprises on private rangelands in Coryell and Hamilton counties was $40.00 per hectare ($16.00 per acre), with the highest average economic value on properties with both livestock and hunting enterprises. Brush manipulation and management is a costly practice that often requires large investments (Conner 2004). Treatment costs for heavy juniper in the North Concho River watershed were estimated at $194.10 per hectare ($78.60 per acre) with an economic value to the landowner of $47.90 per hectare ($19.40 per acre) due to increased forage production for livestock (Bach and Conner 1998). The high treatment costs and relatively low economic value of landowner enterprises supports the need for publicly funded cost-share programs for brush control practices on privately owned rangelands.

Previous Brush Control Program Planning Efforts

Approximately $37 million has been appropriated by the State Legislature to date for brush control work, with the intention of improving water yields from rangelands.

Funds to date have been allocated to selected watersheds based, at-least in part, on research studies with the objective of quantifying the land area of targeted brush species, the expected water yield through hydrologic modeling, and the expected State cost of clearing the targeted brush under a landowner cost-share program. Extensive research also has been conducted to date regarding the expected level of landowner participation in land restoration projects.

Brush Control Feasibility Studies. The first of these feasibility studies was completed in 1998 to estimate the expected increase in water yield and the State cost of controlling the brush on the North Concho River and the Seco Creek watersheds (Walker et al. 1998). A vegetation map of the watersheds was created by classifying Landsat imagery, and a surface hydrology model (Soil and Water Assessment Tool (SWAT)) was used to estimate the change in stream flows based on removal of selected brush categories. The SWAT model is linked to a GIS and utilizes soils, climate, land use/land cover, and elevation data layers. The cost per unit of increased water yield was then calculated for sub-watershed units based on the brush type, method of control, and expected landowner returns from livestock and hunting enterprises (Walker et al. 1998). This method was also utilized for a feasibility study of eight additional watersheds in 2000, and four watersheds in 2002 (Conner et al. 2000; TAES 2002a). The 2000 and 2002 studies assumed removal of 100% of the heavy and moderate brush categories within the watersheds.

An additional comparison study was done by TAES (2002b) for the Twin Buttes watershed and the Edwards Aquifer recharge zone that was based on factors in addition

to maximizing water yield and minimizing the cost per acre-foot of water gained. The study addressed impacts to terrestrial and aquatic wildlife habitat as well as economic considerations of land restoration and maintenance practices. Several brush control scenarios were analyzed that considered slope, riparian area, and total remaining cover restrictions on the brush categories selected for removal. Olenick et al. (2004) utilized the results from the TAES (2002b) study do a multiple criteria analysis of the sub-watershed units within the Twin Buttes watershed and the Edwards Aquifer recharge zone using economic indices for grassland bird habitat production and increased water production as factors in the comparison. The sub-watershed units were then prioritized for brush control based on a weighted importance of the two variables and the expected least cost outcome. Olenick et al. concluded that there were dramatic variations in the efficiencies of water yield and bird habitat returns on investment between the sub-watershed units.

The study methods described above all rely on SWAT model output to estimate the hydrologic impacts of brush removal. The watersheds and sub-watersheds are then compared on the basis of cost per unit water yield increase. The exception is the TAES (2002b) study, which utilized field collected survey data of bird and aquatic habitat to estimate wildlife impacts. Each of the scenarios assumed 100% landowner participation and 100% brush enrollment by participating landowners, again with the exception of the TAES (2002b) study, which included one scenario that required 40% of the watershed to remain covered with existing brush. The SWAT model is a surface hydrology model that uses characteristics of the land surface to adjust site specific surface runoff curve

numbers (Walker et al. 1998). The hydrologic connection between woody plants and streamflow is complex, and predicting the long term impacts that brush removal would have on water yield would require a detailed working knowledge of the groundwater and surface water connections on a local and watershed scale. Our current level of knowledge regarding this connection is limited (Wilcox 2004).

Landowner Participation Research. Research involving landowner participation interests for cost-share brush control projects has been ongoing since about 1998 when plans for the funding of the Texas Brush Control Program were initiated. The research has included mail-out surveys and personal interviews with landowners in North and West Central Texas. Garriga (1998) developed a demographic profile of landowners most likely to participate in a cost-share brush control program in the Edwards Plateau and estimated how much land participants are likely to enroll in the brush control program. Based on 119 responses to a mail-out survey, it was estimated that 66% of the landowners matching the profile of the survey respondents would participate and enroll 51% of their property in a brush control program. The level of cost-share used for the survey would compensate the landowner for the costs of brush control work above that of enterprise returns from increased livestock and wildlife production. In addition, it was concluded that landowners most likely to participate earned greater than 50% of their income from ranching with most of the income from livestock enterprises, owned acreages larger than 810 hectares (2,000 acres), and owned properties more than 121 kilometers (75 miles) from Austin or San Antonio. Thurow et al. (2000) concluded from the same survey results that the landowners preferred an

average of 27% brush cover on their properties, with a current average brush cover of 41%. The results corresponded with the conclusion of a panel of experts, who indicated livestock and hunting enterprises are maximized at 30% brush cover.

Tays (2001) analyzed the factors influencing landowner willingness to enroll in a cost-share brush control program in Blanco and Gillespie counties. Based on 418 responses to a mail-out survey questionnaire, landowners willing to enroll in a brush control program owned an average of 528 acres versus an average ownership size of 220 acres for those not willing to enroll. In addition, landowners living on the property for longer than 10 years were more likely to enroll in a brush control program. Narayanan et al. (2002) investigated landowner willingness to participate in a brush management program in the Edwards Aquifer recharge zone and the Twin Buttes Reservoir drainage area. Results of the study are based on 141 responses in the Twin Buttes Reservoir drainage area and 131 responses in the Edwards Aquifer recharge zone to a mail-out survey questionnaire, and are summarized in Table 1 below.

Table 1. Summary results of Narayanan et al. (2002) investigation of landowner willingness to enroll in a brush management program in the Edwards Aquifer recharge zone and the Twin Buttes Reservoir drainage area.

	Percent Landowner Enrollment			Percent Brush Enrollment	
Study Area	50% Cost-Share	80% Cost-Share	Not Interested	Moderate Cover	Heavy Cover
Edwards Aquifer recharge zone	35%	73%	17%	49%	53%
Twin Buttes drainage area	19%	87%	8%	59%	64%

Note that 17% and 8% of the landowners were not interested in enrolling in a cost-share brush control program in the Edwards Aquifer and Twin Buttes areas, respectively, even if the program compensated the landowner for 100% of the cost to treat the brush.

Sanders (2005) investigated the relationships between landowner and land ownership characteristics and participation in conservation programs in Central Texas. The study involved 60 personal interviews with landowners in Bell, Coryell, Hamilton, and Comanche counties. Sanders (2005) identified three landowner profiles that represented distinct goals, attitudes and motivations regarding land ownership and management. The three profiles include Born to the Land, Ag. Business, and Re-born to the Land types, each of which displayed differences in their willingness to participate in various natural resource conservation programs. A primary objective of the study was to provide a tool for natural resource agencies to profile landowners based on available demographic data, and configure conservation programs accordingly to fit the expectations of the landowner profiles.

Born to the Land and Re-born to the Land owners displayed an attitude of stewardship to the land, while the Ag. Business group generally displayed a "frontier hero" attitude. Born to the Land owners would be more likely to participate in programs promoted with the goal of empowering them to be "the stewards they want to be on their land." Re-born to the Land owners are more likely to participate in programs that provide the knowledge, skills, and subsidies that allow them to be stewards of their land, and Ag. Business owners are more likely to participate in programs that will enhance their economic gains and that best fit their current production focus. In terms of

demographic profiles, Ag. Business owners own on average the largest properties in counties located near urban areas, but the Born to the Land owners owned the largest tracts in the Comanche county, the most rural of the 4 counties sampled. The Born to the Land group had the longest tenure or years of ranching experience, and the Re-Born to the land group had the shortest tenure on the land. Sanders (2005) recommended additional research to develop the demographic information required to more accurately identify the three landowner profiles.

Decision Support Systems and Geographic Information Systems in Environmental Planning

History and Function. There is a connection between economics, planning, and the environment that is receiving increasing attention in policy decisions across the US and also in many other countries. Wright et al. (1993) also indicated that in order to support Legislative decisions, environmental planning must be multidimensional and incorporate social, economic, political, geographic, and technical factors. Decision support systems are tools that provide the connection between these factors. Turban (1988) described the characteristics and function of a well designed decision support system:

1) Bring together human judgment and computerized information.
2) Decision support is provided for individuals as well as groups.
3) Support is provided for all phases of the process: intelligence, design, choice, and implementation.
4) Adaptive over time.
5) Easy to use.

6) Improves the effectiveness of decision making.

Decision support systems were merged with geographic information systems (GIS) in the 1960's when GIS was first utilized to make decisions regarding site suitability analysis (Honea et al. 1991; Wright et al. 1993). The idea of using multiple spatially registered map overlays for spatial analysis was popularized by Ian McHarg in the 1970's (Honea et al. 1991), and was heavily utilized to address many environmental problems with the passing of the National Environmental Protection Act. The environmental crisis movement of the 1960's and 1970's also influenced millions of dollars in research grants for the development of environmental decision support models in the early 1970's (Honea et al. 1991). Image processing systems and landsat data were also born out of these developments.

Several key lessons have been learned since the initial development of decision support systems. Wright et al. (1993) points out that it is important for the developer of a decision support system to remember that common sense knowledge is part of human judgment, and computerized support systems must rely on cognitive skills only. Computerized systems do not have the ability to incorporate emotional processes into decision making criteria – the human interface must provide this key component in the decision making process. In addition, Honea et al. (1991) reminds the developer to not promise more than the system can deliver. In other words, it is important to remember that a GIS cannot answer all of the questions that will be asked of it, and all systems have their limits. It is also important to avoid shackling a system to a specific technology or software that is not widely available to other users.

Examples of Existing GIS Decision Support Systems. It is important to note that decision support systems and GIS could be defined as two separate tools, and effective decision support systems are used extensively without the aid of GIS. However, GIS is increasingly being used as a decision support tool throughout society, and particularly in the field of natural resources management (Honea et al. 1991). The following are examples of the use of GIS as a decision support tool.

The U.S. Fish & Wildlife Service (USFWS) has implemented a GIS decision support system for the Great Lakes Basin to facilitate decision making for land acquisition, environmental review, management planning, and communication/outreach. The system enables quick and reliable access to valuable databases and spatial information regarding rare and endangered species, migratory species, inter-jurisdictional fishes, and colonial water birds from the desktop of all USFWS field stations that manage resources within the Great Lakes Basin (USFWS 2004).

An integrated software package called INFORMS (Integrated Forest Resource Management System) was jointly developed by the USDA Forest Service and the Texas A&M University STARR LAB to facilitate forest resource management decisions. The INFORMS system is coupled with GIS and a relational database management system, and provides a user interface and access to geographically oriented resource data and knowledge provided by Forest Service experts to assist in project planning, alternative development, and environmental assessment (Loh et al. 1994).

Thompson (1996) developed a GIS decision support system within the North Columbia Mountains of interior British Columbia to evaluate conflicts and access

tradeoffs of competing timber, wildlife, and recreation land uses. Caribou habitat was identified using elevation, slope, aspect, and vegetation data layers, and surveys were conducted to determine the economic value and locations of recreational uses including heli-skiing, hunting, snow-mobiling, and heli-hiking. The data layers were overlaid to allow a visual display of the land use conflicts, and an economic comparison of five timber harvesting scenarios was made using a multiple accounts method.

A GIS decision support system was also developed in Manitoba, Canada to identify endangered species habitat as well as determine the habitat areas that could be potentially protected. Multiple layers including surface geology, mineral maps, soils, ecoregions, watersheds, and political boundaries were collected and overlaid to support policy decisions made by the government for endangered species management (Baijal 1996).

Summary

The primary motive for publicly funded land restoration programs in Texas to date has been brush control for increased water yield. While water supply issues in Texas will remain a high priority, increasing attention is being given to a more holistic approach to land restoration projects with a focus on improving the ecological condition of privately owned rangelands. Improved ecological conditions have the potential for enhanced water quality, increased bio-diversity, improved wildlife habitat, and greater economic and aesthetic returns to the landowner.

Planning and implementation of more holistic land restoration projects will require an assembly of data such as that provided in a decision support geographic

information system (DSGIS). Policy and implementation decisions for future land restoration projects should be made on the basis of our best available knowledge regarding the targeted geographic area such as existing vegetation cover, ecological condition, endangered species habitat concerns, landowner size and numbers, and estimated public costs.

CHAPTER III

METHODOLOGY

Development of an effective decision support geographic information system (DSGIS) for land restoration projects has required a multi-disciplinary approach that utilizes the results from several different research efforts. The past and ongoing research efforts that support this study, data collection efforts, data analysis, and geographic information system (GIS) tasks are all described in the following sections.

It is important to note that one of the benefits of a DSGIS is the ability to develop a similar type of system for other geographic regions in Texas where Ashe juniper encroachment on private lands has led to public concerns. The GIS data layers were all developed using data widely available for the entire state of Texas, and in many instances the entire United States. Thus, a similar system could potentially be developed for other regions in the State using the same data sources and similar processing steps as those described herein.

Study Area Description

The study area chosen for the DSGIS includes the Bosque, Lampasas, and Leon River watersheds, all of which are within the Brazos River basin and located in Central Texas (Fig. 2). These three watersheds encompass approximately 1,791,800 hectares (4,426,000 acres) and lie mostly within 12 different counties. The Lampasas Cut Plain, Grand Prairie, and Western Cross Timbers natural regions, as defined by Texas Parks and Wildlife, encompass about 87 % of the study area. The study area is bordered to the southeast by the Blackland Prairie and to the northwest by the Mesquite Plains. An east

to west annual rainfall gradient from about 864 mm (34 in) to 660 mm (26 in) per year can be found within the study area.

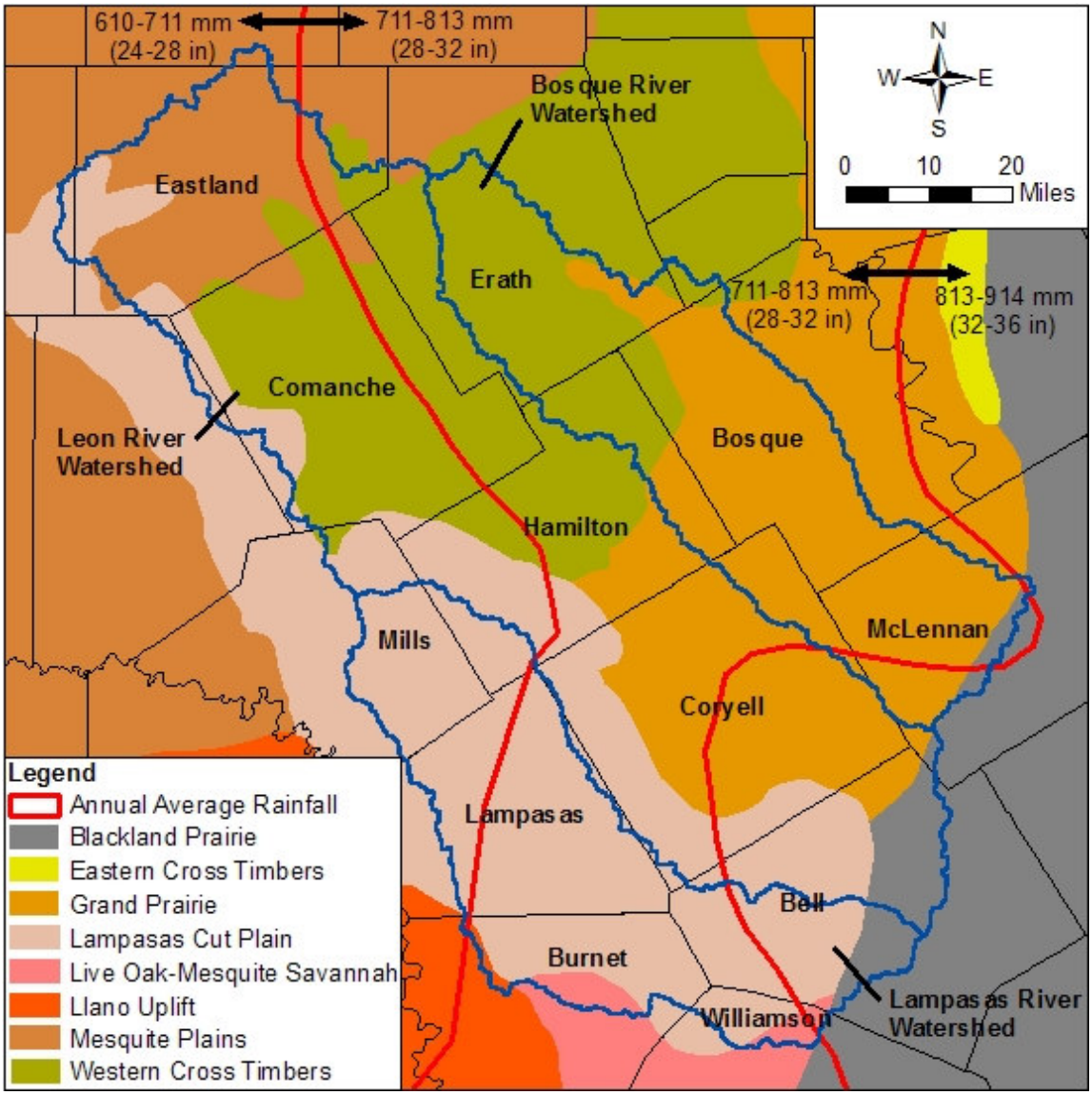

Figure 2. Map of the study area including Texas Parks and Wildlife natural regions and average annual rainfall totals.

The study area is characterized by mostly rural, privately owned rangeland and farmland that drains into three major reservoirs including Stillhouse Hollow Lake, Belton Lake, and Lake Waco. These reservoirs are a major water supply source for the metropolitan areas of Georgetown, Killeen, Temple, and Waco. Fort Hood, an approximately 88,600 hectare (219,000 acre) United States Army base, is located in Coryell and Bell counties in the Leon River watershed. Fort Hood is the source of a growing interest for mitigating the preservation of endangered species habitat in the study area, and the rapidly growing urban centers are the source of a growing public interest in the enhancement of water quantity and water quality from the upstream watersheds.

Contribution from Leon River Restoration Project (LRRP)

The LRRP is a research scale brush control program within the Leon River watershed of Hamilton and Coryell Counties. The primary objective of the research project is to quantify the impacts of Ashe juniper removal and management on rangeland water yield and quality, wildlife habitat, and forage production for livestock (Hamilton 2004). The Ashe juniper removal and management practices are implemented on selected private rangelands that are potential habitat for the golden-cheeked warbler and/or the black-capped vireo, both of which are listed as endangered species. The following major objectives have been identified for the LRRP research components:

1. To evaluate changes in water yield and water quality resulting from brush management.

2. To improve wildlife habitat and increase populations, including the federally listed black-capped vireo and golden-cheeked warbler.
3. To incorporate long-term management practices to evaluate water and wildlife improvements.
4. To assess and analyze the economic impacts of the project on participating landowners.
5. To quantify the impacts of Ashe juniper removal and rangeland management on water, wildlife, and forage production for livestock in a way that optimizes transferability of the data to similar areas.

Phase I of the LRRP, which includes the pre-treatment research efforts, was completed in September 2004. Phase I quantified the vegetation characteristics, hydrologic parameters, endangered species populations, and landowner enterprise value on private properties prior to Ashe juniper removal. Phase II is ongoing as of this writing, and will quantify the impacts associated with the removal and management of Ashe juniper.

The research efforts of the LRRP are correlated, to the extent possible, to ecological sites within the study area. The development of ecological site boundaries and descriptions for similar geographic areas outside of the study area has facilitated the transferability of the knowledge gained through the LRRP to other areas. The study area for the DSGIS was strategically located to surround Hamilton and Coryell counties so that the results of the LRRP could be systematically applied to the surrounding watersheds via similar ecological sites. The data layers developed for the DSGIS have

relied heavily on the research efforts of the LRRP, and the scope of this study would not have been possible without them.

Decision Support Geographic Information System (DSGIS) Layer Development

The geographic information system (GIS) software utilized for the study was ArcView, Version 9.0, by ESRI. The GIS datasets were developed using ArcView software with the exception of the vegetation map, which was developed using IDRISI Kilimanjaro, Version 2004, by Clark Labs. The DSGIS is based largely on raster datasets at a 30-meter resolution. This resolution corresponds to the available resolution of the input data files used to produce several of the data layers. A 30-meter resolution is adequate for the level of detail required of the DSGIS and is necessary to reduce the computing power required to process large geographic areas. The GIS datasets are projected using the Universal Transverse Mercator Zone 14 North coordinate system, and referenced to the North American Datum of 1983.

Supporting Datasets. Several datasets were downloaded at no cost from government websites and utilized in the DSGIS. Digital soil survey data was obtained from the Natural Resource Conservation Service (NRCS) for each county within the study area. The dataset consists of a polygon boundary for each soil survey unit, which corresponds to the original Soil Conservation Service (SCS) county soil survey maps. This dataset is the finest resolution of soil type data that is widely available. The soil survey units were converted to ecological sites using a database of soil survey unit characteristics (included with the datasets) and an ArcView Version 3.2 software extension developed by the NRCS titled Soils Data Viewer. The ecological sites layers

for each of the counties were then merged into a single polygon file and converted to a 30-meter raster layer.

A 30-meter resolution digital elevation model (DEM) was obtained from the United States Geological Survey (USGS) National Elevation Dataset (NED). The elevation data was downloaded in one degree blocks and merged to form a seamless DEM for the study area. A vector layer representing the streams and rivers in the study area was obtained from the USGS National Hydrologic Dataset (NHD). County and urban area boundaries were obtained from the US Census Bureau, and vector files representing the roads and highways in the project area were obtained from the Texas Department of Transportation.

Vegetation Layer. A 30-meter resolution vegetation layer was developed representing juniper, liveoak, deciduous, and non-woody vegetation types within the study area. The layer provides the capability to quantify the amount of juniper within the study area as well as to identify the areas where juniper encroachment is a problem. The liveoak and deciduous pixels were used to further characterize the woody areas, which is important in the endangered species habitat potential layer as well as in evaluation of treatment costs as explained below.

The vegetation layer was developed from a supervised classification of 30-meter resolution Landsat imagery purchased from the USGS. Three satellite scenes with acquisition dates of January 13, 2002 and March 9, 2002 were required to provide coverage for the entire study area. Each scene includes 9 images representing different bands of spectral wavelength, including blue, green, red, infrared, and thermal bands. A

winter-time (dormant season) scene was selected for the classification process to more effectively isolate the spectral signature of the evergreen juniper vegetation. The winter-time scene also provided a greater spectral distinction between the liveoak, deciduous, and non-woody vegetation types, versus imagery taken during the growing season.

A maximum likelihood hard classifier routine and IDRISI Kilimanjaro image processing software was used for the supervised classification. Field verified training sites were first delineated in order to develop spectral signatures representing the different targeted classes of vegetation. Training sites were developed for 21 different spectral classes in addition to the final four vegetation types. The number of spectral classes was necessary to distinguish the complex spectral signatures of the satellite imagery. Examples of the different classes include winter wheat, water, dense stands of shin-oak, roads and concrete, juniper thickets and light stands of juniper, and prickly-pear and broomweeds. The multiple vegetation classes were combined to make up the final four vegetation types as a final step in the classification process. Development of the vegetation layer was an iterative process of refining the training sites and associated spectral signatures, running the maximum likelihood classification routine, and verifying the results. Fortunately, field experience with the LRRP and familiarity with the vegetation cover for properties within Coryell and Hamilton counties allowed much of the verification process to be done in-house with the help of high resolution aerial photography. Drive-through trips were also conducted in the study area using real-time geographic positioning system (GPS) positioning data overlaid on the classified imagery to verify the results.

The initial drive-through field verification trips revealed an unexpected issue with the re-growth juniper spectral signature. The dense, older juniper thickets have a unique spectral signature and were accurately identified; however, the scattered regrowth stands have a spectral signature very similar to thick stands of deciduous trees and shrubs found in western Hamilton county, Comanche county, and northwestern Erath county. Much of this area was initially classified as regrowth juniper when it actually does not grow in these regions. Further analysis of the imagery and field verification indicated that the regrowth juniper stands usually occurred within 2,000 meters from the juniper thickets, likely due to seed transport limits and limits of desirable ecological conditions for juniper. Thus, a 2,000-meter radius buffer zone was created around each of the juniper thicket pixels to define the areas where the regrowth juniper would more likely be found. IDRISI Kilimanjaro has the capability to adjust the probability that each pixel belongs to a specified spectral class, based on a probability image for that spectral class. The probability is normally set to an equal value for all of the spectral classes. In other words, for 10 different spectral classes the probability that any given pixel would belong to each class is normally equal with a probability value of 0.10. However, in this case the probability that a pixel lying outside the 2,000-meter buffer zone belonged to the regrowth juniper class was reduced to 10% of the probability for belonging to the remaining 20 classes (.0048 versus an equal .048 for 21 classes). The buffer zone resulted in a juniper vegetation map that more accurately represented the large regions in the study area that are known to be void of juniper. A final accuracy check was done using field collected vegetation data from approximately 21 kilometers (13 miles) of

transects established as part of the LRRP Phase I research efforts. Additional detail regarding the accuracy of the classified imagery is discussed in Chapter IV.

Endangered Species Habitat Layer. An endangered species habitat layer was developed that identifies areas with high, moderate, and low potential for golden-cheeked warbler habitat. The U.S. Fish and Wildlife Service recovery plan for the golden-cheeked warbler identifies tasks of identifying and protecting existing habitat on private and public lands as well as managing for golden-cheeked warbler habitat on these lands (USFWS 1992). The layer facilitates an estimate of the quantity of available golden-cheeked warbler habitat within the study area as well as identification of sub-regions where golden-cheeked warbler habitat is most predominant. The black-capped vireo is also found within the study area; however, the preferred habitat for this endangered species is more difficult to map given the type and resolution of GIS data that is widely and readily available. Black-capped vireo habitat was consequently excluded from the endangered species mapping effort.

The habitat model is based on the results of two recent studies to predict nesting locations for the golden-cheeked warbler. Magness et al. (2005) analyzed the impacts of landscape scale vegetation composition on golden-cheeked warbler occurrence in Bandera county, Texas. The study compared the influence of landscape-scale vegetation variables on the results of presence/absence surveys conducted at 202 point locations. The percentage of juniper-oak woodland within a 400-meter radius surrounding the survey points was the most important variable for describing the presence of golden-cheeked warblers. Magness et al. (2005) concluded that “golden-cheeked warblers

occurred in a local habitat only when landscape composition exceeded 40% woodland and likelihood of occurrence exceeded 0.50 only when landscape composition exceeded 80% woodland." Juarez (2004) conducted presence/absence surveys of golden-cheeked warblers at 378 point locations distributed across Coryell and Hamilton counties as part of the LRRP research efforts. It was concluded that the presence of golden-cheeked warblers was positively associated with the increasing density of large juniper trees and deciduous oaks. An analysis of the golden-cheeked warbler hits in relation to ecological sites concluded that 27% of the hits were found on low stony hill sites and 43% were found on steep adobe sites. Furthermore, 60%, 76%, and 83% of the golden-cheeked warblers were found within 50 m, 100 m, and 150 m of steep adobe ecological sites, respectively.

Two GIS datasets were used to develop the golden-cheeked warbler habitat model: the vegetation layer and the ecological sites data layers described above. The vegetation layer was first used to define zones of low, moderate, and high habitat potential based on the Magness et al. (2005) study, and the ecological sites layer was then used to refine these categories based on the Juarez (2004) study. A 400-meter moving windows procedure was calculated using IDRISI Kilimanjaro on the juniper and deciduous pixels in the vegetation layer. The moving windows analysis calculates the percentage of occurrence (0-100%) of a given pixel value within a specified zone surrounding every pixel in the image. The combined juniper and deciduous pixels were used to represent the percentage of juniper-oak woodland on a landscape scale as described by Magness et al. (2005). The liveoak pixels were excluded from the analysis

due to the preference of deciduous oaks by the golden-cheeked warblers (Juarez 2004). The pixels with a value of juniper-oak woodland cover of less than 40% within a 400-meter radius were categorized as low habitat potential, the pixels with a value of 40%-80% were categorized as moderate habitat potential, and the values of greater than 80% juniper-oak woodland were categorized as high habitat potential.

Based on the vegetation mapping efforts described above, juniper is not found within a large portion of the mesquite plains and western cross timbers natural regions (Fig. 2). However, many of these regions of little or no juniper cover (including some smaller areas within regions where juniper is found) include deciduous cover of greater than 40% within a 400-meter radius. Based on the methods used to describe juniper-oak woodland, the moving window analysis of these areas resulted in a percentage of juniper-oak woodland cover of greater than 40%. It would be inaccurate to classify these areas void of juniper cover as golden-cheeked warbler habitat just because the deciduous cover is greater than 40%. Therefore, the results of the juniper-oak woodland moving windows analysis was classified as moderate and high habitat potential zones only if the total juniper cover within the 400-meter radius was greater than 15%.

The final step in the development of the habitat potential layer was to overlay the ecological site boundaries for steep adobe and low stony hill sites on the habitat potential categories developed per the Magness et al. (2005) study. This facilitated a refinement of the initial categories based on the Juarez (2004) study (Fig. 3). The following methodology was used to re-classify the original habitat potential areas based on the preferred low stony hill and steep adobe ecological sites:

1. The original high and moderate potential habitat areas remained unchanged only if located within a preferred ecological site.
2. If the original high potential habitat areas were not located within a preferred ecological site, they were reduced to a moderate category.
3. If the original moderate habitat potential areas were not located within a preferred ecological site, they were reduced to a low category.
4. The original low habitat potential areas remained unchanged.

The accuracy of the golden-cheeked warbler habitat potential layer was analyzed using presence/absence survey results of 709 survey points located in Coryell and Hamilton counties. The presence/absence surveys were conducted in 2003 and 2004 as part of the LRRP Phase I research efforts. A portion of this field data was collected as part of the Juarez (2004) study described above, and the remaining was collected as part of an ongoing study of the LRRP (unpublished data by Tiffany Cummins at Texas A&M University Wildlife and Fisheries Department 2005). The accuracy of the layer is described in further detail in Chapter IV.

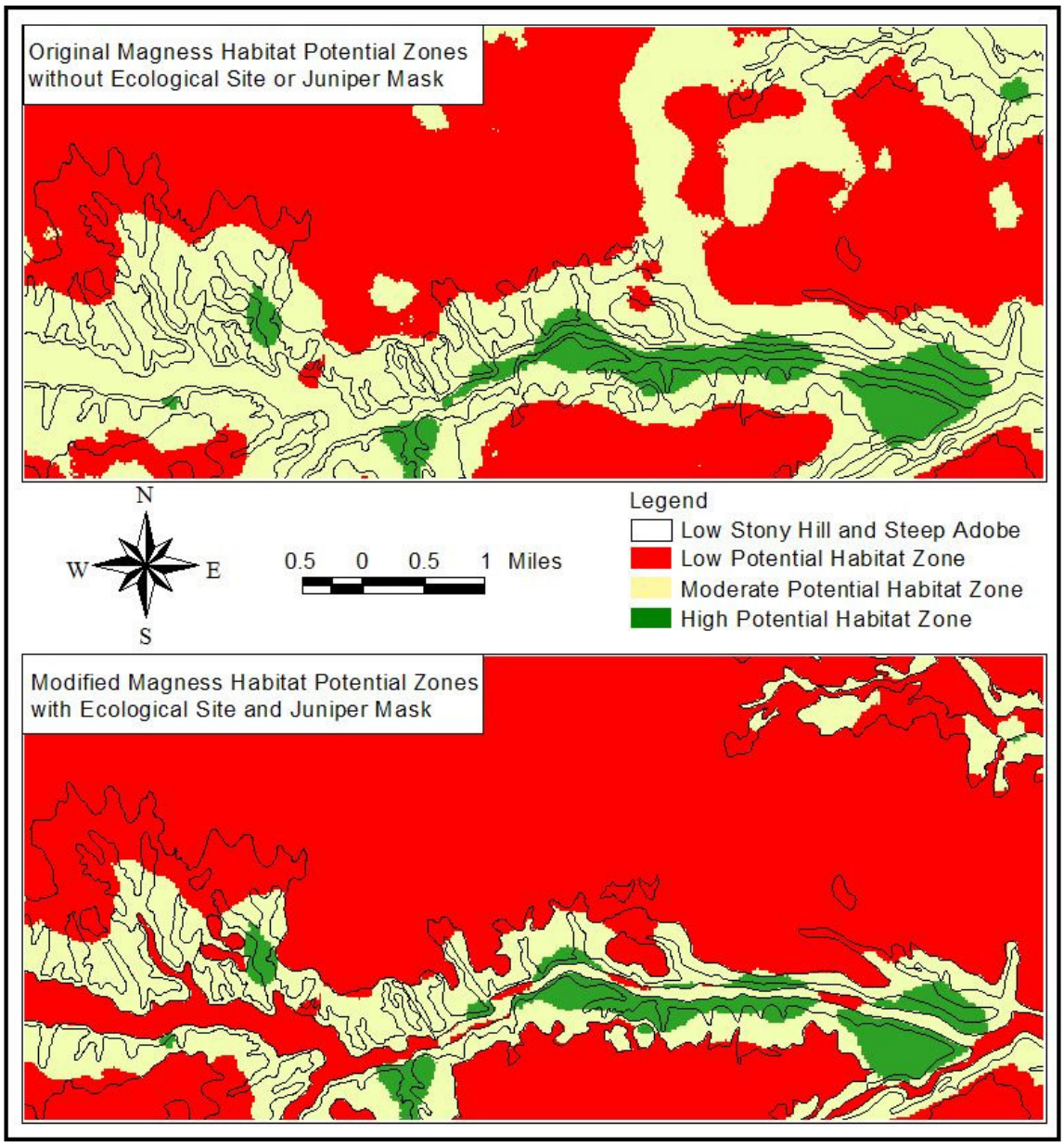

Figure 3. Re-classification of the Magness et al. (2005) based categories for likelihood of occurrence of golden-cheeked warblers. The Magness et al. (2005) categories are based on the percentage of juniper-oak woodland in a 400-meter radius moving window. Re-classification is based on the ecological site results of the Juarez (2004) study.

Private Property Boundary Layer. In order to effectively plan and apply land restoration efforts within privately owned rangelands, knowledge regarding the size, location, and ownership of individual tracts is critical.

The United States Department of Agriculture (USDA) Farm Service Agency (FSA) is responsible for the administration of federally funded support programs for farmers and ranchers across the United States. The FSA maintains records and maps of parcel boundaries for every landowner that has received federal aid or is enrolled to receive information regarding potential federal aid. This information is traditionally housed in local county offices in hardcopy format; however, a recent homeland security initiative has resulted in the development of digital tract boundaries and a standardized database based on the maps and records maintained by the local county offices. The property boundaries have been digitized at the state level and are in ArcView shapefile format. This information is, of course, highly sensitive and not available to the general public. However, due to the working relationship between the USDA and the efforts of the LRRP, this information was made available for the counties within the study area for the purpose of planning for land restoration projects. A contingency for the use of this data was the removal of landowner information from the property boundaries, with the exception of an FSA tract number. The FSA tract number may be used in the future to retrieve the landowner information from the FSA database given the proper clearances and approval of the FSA. Although registration with the FSA is voluntary, property boundaries were obtained for approximately 95% of the privately owned rural lands within the study area.

Several steps were taken to configure the raw FSA property boundary data files into the dataset included with the DSGIS. The FSA has digitized individual pastures and cultivated areas located within each of the properties, which is of little utility given the goals for the DSGIS. The multiple polygons within the individual properties were reduced to a single polygon representing each ownership tract with a unique FSA tract number. Even if a single landowner owns two parcels in opposite ends of the county, they are represented by a single FSA tract number, and polygon, within the DSGIS. It is important to note, however, that some landowners sign on with the FSA using multiple tract numbers. This is typically the case with landowners responsible for large tracts of land. These cases were impossible to disseminate and were treated as separate landowners for the analysis.

The next step was to combine the multiple layers representing each of 12 counties into a single property boundary layer. FSA data was not acquired for Stephens, Somervell, Brown, and Callahan counties because only a small percentage of these counties lie within the study area. Several of the property boundaries along the edges of the counties within the study area overlapped, causing conflict with the data from neighboring counties. These conflicts were resolved by deleting the overlapping tract that fell outside its respective county boundary. If the conflicting polygons overlapped a county boundary, the tract with the smallest percentage of area within its respective county was deleted. The FSA tract numbers are only unique to the tracts within a given county. The final step was to assign a unique identifier to each of the property boundary

polygons. The unique identifier includes the county name and the original FSA tract number.

Landowner Participation and Treatment Costs

Landowner participation and treatment costs are significant factors to be considered in the planning and implementation of land restoration programs. This section provides an overview of the expected level of landowner participation for land restoration programs based on previous research efforts in North and West Central Texas. In addition, a discussion of the methodology for an analysis of the actual treatment costs of the LRRP is followed by a discussion of how these data were incorporated into the DSGIS.

Landowner Participation. The research to date regarding landowner participation indicates that the actual area of land impacted by a land restoration project targeting privately owned lands is dictated by two variables: The percentage of landowners willing to participate in the program and the percentage of their property that they are willing to enroll in the program. These two variables are influenced by many factors including the objectives and presentation style of the land restoration program, management goals of the landowner, personal motivations of the landowner, and economic considerations. These factors are much too complex to predict the actual level of participation and subsequently quantify the expected land area that would be impacted on a local scale. As indicated in recent research studies, landowner participation predictions would likely be more accurate at a county or a major watershed scale.

The landowner participation research described in Chapter II was utilized to analyze a potential Ashe Juniper brush control program. The actual land area of Ashe

juniper that would likely be cleared under a specified brush control program for each of the county and major watersheds in the DSGIS study area was predicted using an expected participation level. For purposes of the study and to parallel the research efforts to date, it is assumed that the cost-share level of the potential brush control program would offset any treatment costs above the expected economic returns to the landowner. Based on the study results of Garriga (1998) and Narayanan et al. (2002), about 65% of the landowners in the study area would likely participate in an Ashe juniper brush control program, and about 50% of the available juniper on each of the enrolled properties would likely be treated. Therefore, for this study, it is assumed that approximately 32.5% of the available Ashe juniper in the project area would be cleared.

LRRP Treatment Cost. To provide information regarding treatment costs for Ashe juniper removal and management, available records and data collected from the LRRP were analyzed and interpreted. Actual treated area boundaries were mapped as part of the LRRP using a GPS. The GPS treated area boundaries along with machine hour records maintained by the LRRP were used to estimate treatment costs per unit area of the treated areas. The GIS layers described above were then used to quantify various parameters of the treated areas including pre-treatment juniper density, type of ecological sites, and density of non-juniper woody species in an attempt to explain the variability of the treatment costs.

Incorporation of Research into DSGIS. To provide an indicator of the total cost of an Ashe juniper brush control program, the average per unit area treatment cost of the LRRP was then multiplied by the expected land area of Ashe juniper cleared for

each of the counties and major watersheds in the DSGIS study area. The total expected quantity of juniper treated along with expected costs to clear the juniper are summarized in Chapter IV.

Prioritization of Geographic Areas for Restoration Practices

An objective of any well planned land restoration program is to maximize the expected benefits of the program with a limited amount of available resources. This typically would require directing available resources to manageable, targeted regions with ownership and ecological characteristics that would most likely benefit from the restoration program goals. The data layers of the DSGIS were utilized to target and prioritize geographic areas for an Ashe juniper brush control program and a golden-cheeked warbler habitat restoration project. Sub-watershed boundaries delineated using the National Elevation Dataset (NED) and the National Hydrologic Dataset (NHD) as well as county boundaries were used to define the geographic areas (Fig. 4). Sub-watershed outlet points and names were first manually defined using the stream data of the NHD. The upstream watershed boundaries for each of the outlet points were then automatically defined using the NED and the hydrologic functions of the ArcView Spatial Analyst extension. One hundred and eighty-eight (188) sub-watershed boundaries were delineated within the study area, with an average size of 9,530 hectares (23,540 acres). Each of these sub-watersheds were named according to the stream names in the NHD database. A listing of the sub-watershed names, locations, and sizes are included in Appendix A.

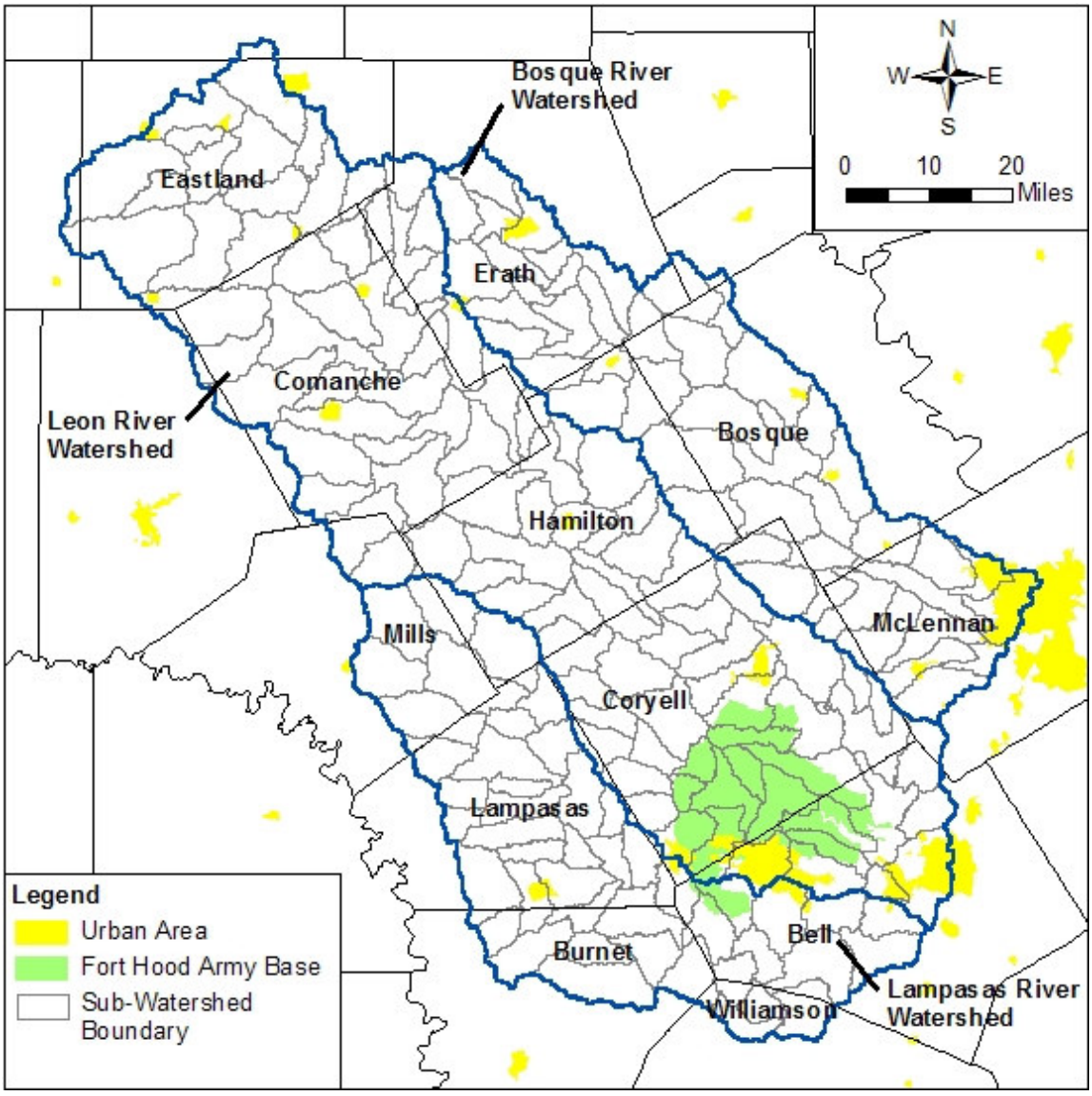

Figure 4. Map of the study area including sub-watershed boundaries and county boundaries, both of which are used to identify and prioritize geographic sub-regions for land restoration practices.

The variables considered for the prioritization analysis were density, quantity, and location of Ashe juniper and potential golden-cheeked warbler habitat, percentage of privately owned rangeland as well as landowner tract size and numbers derived from the

FSA property boundaries. Areas within Fort Hood were excluded based on the percentage of privately owned rangeland. In addition to targeting geographic areas at a sub-watershed and county scale, procedures were also developed to target individual landowners on a local scale for Ashe juniper brush control or golden-cheeked warbler habitat restoration projects.

CHAPTER IV

RESULTS

This chapter will present the results of the Decision Support Geographic Information System (DSGIS). The first sections will illustrate the accuracy of the data layers based on field collected data. A summary of the density, quantity, and location of the key data layers is then presented followed by an analysis of Ashe Juniper treatment costs. Finally, the procedures for prioritizing sub-regions and properties within the project limits for land restoration projects are presented and summarized.

Accuracy Analysis of Data Layers

The accuracy of the vegetation and golden-cheeked warbler habitat potential layers was analyzed using field collected data from the Leon River Restoration Project (LRRP). The accuracy of the private property boundary layer was verified during personal landowner interviews conducted in Coryell county, also a part of the LRRP research efforts. In addition to the field verified accuracy of the layers, the recommended uses and limitations of the layers are also discussed in this section.

Vegetation Layer. The ground truth data used to verify the accuracy of the vegetation layer was collected as part of the LRRP research effort. Approximately 21 kilometers (13.1 miles) of line transects were set and marked using a handheld geographic positioning system (GPS) on private properties in Hamilton and Coryell counties (Holland et al. 2004). The general location of the transects with respect to the DSGIS study area are shown in Figure 5. The primary objective for the transects was to document the pre-treatment composition of herbaceous vegetation, ground cover, and

woody cover for selected ecological sites and for small 0.4 to 6.1 hectare (1 to 15 acre) watershed plots in the LRRP project area.

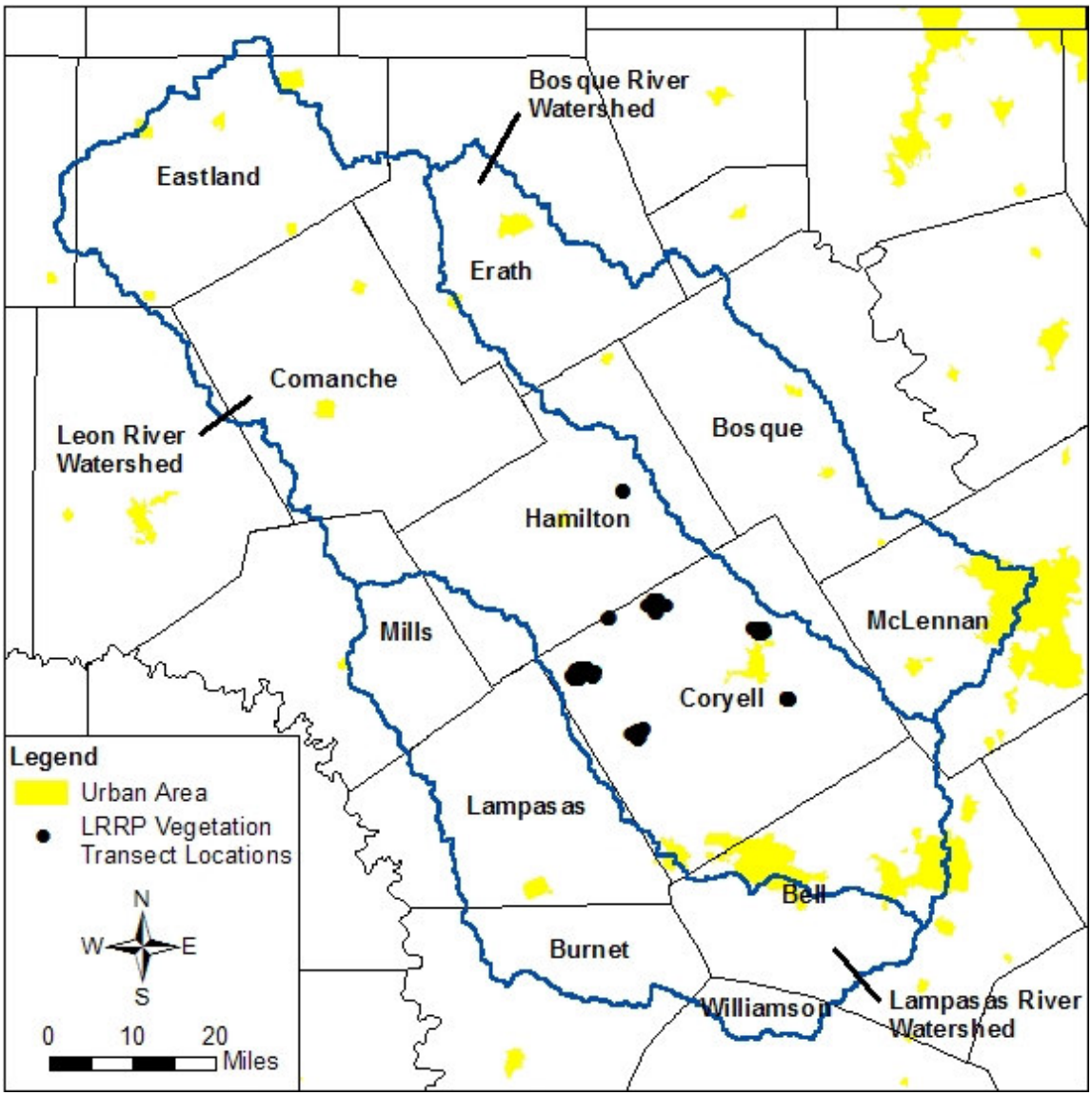

Figure 5. Map showing the general location of the LRRP vegetation transects in Coryell and Hamilton counties.

The woody cover component of the transects was utilized for this study and was summarized into percent cover of juniper, liveoak, deciduous, and non-woody cover categories to match the vegetation types derived from the Landsat satellite imagery. The transects were summarized into 38 individual units with total lengths ranging from 67 to 2,258 meters (220 to 7,408 feet).

The transect lines were overlaid on the vegetation layer in ArcView and the percent cover of the juniper, liveoak, deciduous, and non-woody vegetation types were derived for each of the transects based on the proportionate length of the lines that overlapped each pixel category. This facilitated a comparison of the field collected percent cover values with the classified imagery results based on each of the 38 individual transects (Table 2) as well as for the total group of transects (Table 3).

Table 2. Individual accuracy of juniper, liveoak, deciduous, and non-woody vegetation type categories of the vegetation layer based on 38 individual ground transects.

		Percent Accuracy		
Vegetation Type	Number of Transects	Mean	Standard Deviation	95% Confidence Interval
Juniper	38	82	17.6	76 - 88
Liveoak	38	93	7.0	91 - 95
Deciduous	38	88	15.7	83 - 93
No Woody	38	75	18.6	68 - 81

Comparison of the field transects to the vegetation layer on the individual transect scale allows the derivation of statistics for the individual accuracy values. It is important to note that the actual percent cover values presented in Table 3 add up to 110%. This is because of overlapping vegetation type canopies incurred in the field. The vegetation

map percent cover values add to 100% because the imagery pixels do not represent overlapping canopies.

Table 3. Overall vegetation layer accuracy and individual accuracy of juniper, liveoak, deciduous, and non-woody vegetation type categories based on the total percent cover of 21 kilometers of vegetation transects.

Vegetation Type	Transect Length (m)	Actual Percent Cover	Vegetation Map Percent Cover	Percent Accuracy
Juniper	21,059	37%	48%	89%
Liveoak	21,059	6%	11%	95%
Deciduous	21,059	15%	11%	96%
No Woody	21,059	52%	30%	78%
			Average:	**89%**

The results of the two different methods for analyzing the accuracy of the vegetation layer are encouraging. The average accuracy of the four vegetation types is between 75% and 93% at the individual transect or local scale, and between 78% and 96% when the percent cover data for the transects were summed into a single value to represent a landscape scale. The overall average accuracy is estimated at 89%. The accuracy of the vegetation layer increases as the scale increases, likely due to the relatively coarse resolution of the 30-meter pixels. The accuracy of the vegetation layer would significantly deteriorate at scales representing areas less than about 9 pixels, or 0.8 hectares (2.0 acres). However, the results indicate that the accuracy of the vegetation layer is more than acceptable at local scales representing individual transect lengths of 67 to 2,258 meters (220 to 7,408 feet).

Golden-cheeked Warbler Habitat Potential Layer. The accuracy of the golden-cheeked warbler habitat layer was analyzed using presence/absence surveys conducted in Hamilton and Coryell counties as part of the LRRP research efforts (Fig. 6).

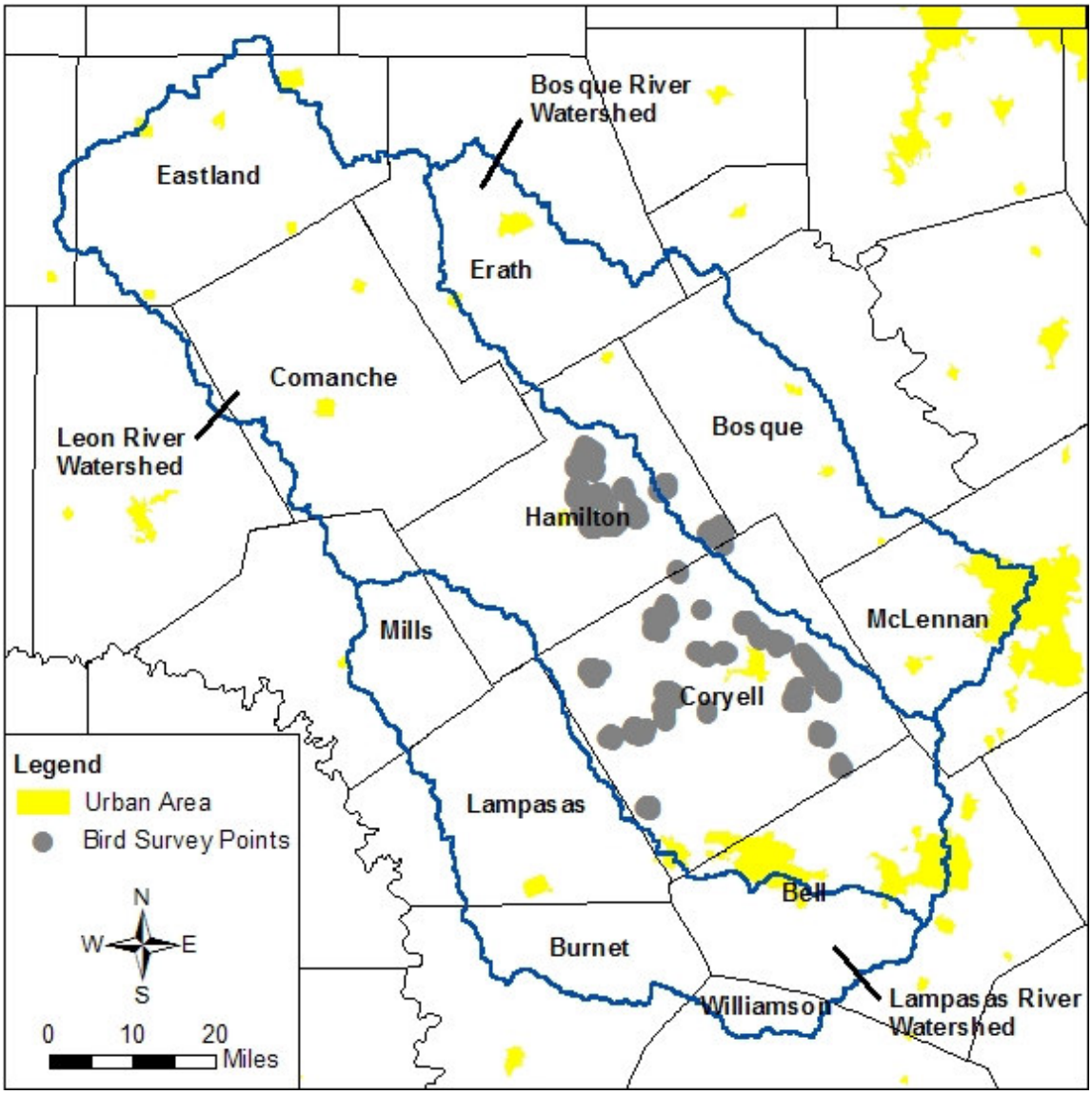

Figure 6. Map showing the general location of the 2003 and 2004 LRRP bird survey points in Coryell and Hamilton counties.

Bird surveys were conducted at 709 point locations in the spring of 2003 and 2004 (Juarez 2004; unpublished data by Tiffany Cummins at Texas A&M University Wildlife and Fisheries Department 2005).

The bird survey points were overlaid on the habitat potential layers and a corresponding habitat layer category value of high, moderate, or low potential for golden-cheeked warbler presence was assigned to each of the points. These values were then compared to the actual field collected presence/absence data for the points. A matrix of the results is presented in Table 4.

Table 4. Matrix of predicted versus observed presence of golden-cheeked warblers based on 709 survey points overlaid on high, moderate, and low habitat potential layer categories.

		Predicted (Point Totals)			
		High	Moderate	Low	Total
Observed (Point Totals)	Occupied	43	111	22	176
	Not Occupied	34	224	275	533
	Total	77	335	297	709

		Predicted (Percent)			
		High	Moderate	Low	Total
Observed (Percent)	Occupied	6%	16%	3%	25%
	Not Occupied	5%	32%	39%	75%
	Total	11%	47%	42%	100%

Golden-cheeked warblers were observed at 176, or 25%, of the 709 bird survey points. Of the 176 occupied points, 88% of them were located in high or moderate habitat potential zones. Although 297, or 42%, of the total 709 points were located in low habitat potential zones, only 7% (22 of 297) of these were occupied. In addition, 56% and 33% of the points located in high and moderate habitat potential zones were occupied, respectively. These results correspond with the Magness et al. (2005) golden-cheeked warbler habitat mapping effort in Bandera county, Texas. She concluded that the likelihood of occurrence exceeded 0.50 only when landscape composition exceeded 80% woodland. The high potential zone in the habitat potential layer is based on a landscape composition of greater than 80% woodland, as described in Chapter III.

In order to gain an understanding of the overall accuracy of the layer, the percentage values of the matrix presented in Table 4 can be converted into a binomial matrix (Table 5). The high and moderate prediction categories were combined to represent an overall "habitat" prediction category.

Table 5. Binomial matrix of predicted versus observed presence of golden-cheeked warblers based on 709 survey points overlaid on high, moderate, and low habitat potential layer categories.

		Predicted (Percent)		
		Habitat	Non-Habitat	Total
Observed (Percent)	Occupied	22%	3%	25%
	Not Occupied	36%	39%	75%
	Total	58%	42%	100%

The overall accuracy can be obtained by adding the percentage of occupied sites that are in the moderate and low potential zones and the percentage of non-occupied sites that are in the low potential habitat zone. If the layer were 100% accurate, none of the occupied points would fall in a low habitat potential zones, and none of the non-occupied points would fall in a moderate or high habitat potential zone. Based on this method, the golden-cheeked warbler habitat layer is 61% accurate. It is important to note, however, that this method for accuracy assumes that 100% of the potential habitat in the study area would be occupied by an endangered species, which is clearly not the case. Because the golden-cheeked warbler is an endangered species, it is expected that a significant number of the survey points located in designated habitat areas would not be occupied (63% in this case). It is therefore concluded that the accuracy of the layer is more than adequate for purposes of designating areas as low, moderate, or high potential for golden-cheeked warbler habitat.

Further analysis of the accuracy of the golden-cheeked warbler map indicates that its use would result in approximately 13% of the occupied areas not being designated as potential habitat (22 out of 176 occupied points are in low habitat areas). This is a trade-off in the methodology selected for the development of the layer. As described in Chapter III, the methodology developed by Magness et al. (2005) was modified by the results of the Juarez (2004) study to develop the final habitat layer. This modification resulted in a significant reduction of the areas designated as potential habitat (Fig. 3 in Chapter III) and came at the cost of a higher potential for the exclusion of some occupied areas being designated as habitat. However, the downfall of the

unmodified Magness et al. (2005) approach is that significantly more non-occupied points fall into areas designated as potential habitat. A comparison of the accuracy of the two procedures for the Coryell Creek watershed area using the presence/absence survey points and a binomial matrix (similar to that shown above in Table 5) resulted in an overall estimated accuracy of 41% for the unmodified Magness et al. (2005) methodology, and 56% for the final habitat layer. Modification of the original Magness et al. (2005) approach results in a more accurate, efficient designation of potential habitat.

Private Property Boundary Layer. The accuracy of the private property boundary layer was not necessarily quantified as part of this study. However, the use of the layer merits a discussion of the observed accuracy and the level of detail included in the development of the layer by the Farm Service Agency (FSA). As described in Chapter III, the property boundaries were originally developed by hand drawing lines on hardcopy aerial photography mapping and through consultation with the landowners. The digitizing process recently conducted by the FSA matched the level of accuracy found on the original aerial photographs. Figure 7 illustrates the typical level of detail found in the layer across the project area. Note how the boundaries follow the highway and county road boundaries.

Landowner interviews were conducted in Coryell and Hamilton counties as part of the economic research efforts of the LRRP (Jones and Conner 2004). As part of the interview process, aerial photography maps were prepared that included the FSA property boundary data. The property boundaries were verified by the landowners

during the interview, and were consistently accurate for each of the 29 interviews conducted with the exception of minor changes or changes due to recent property acquisitions. The accuracy and detail of the property boundary layer is more than adequate to meet the objectives of the DSGIS.

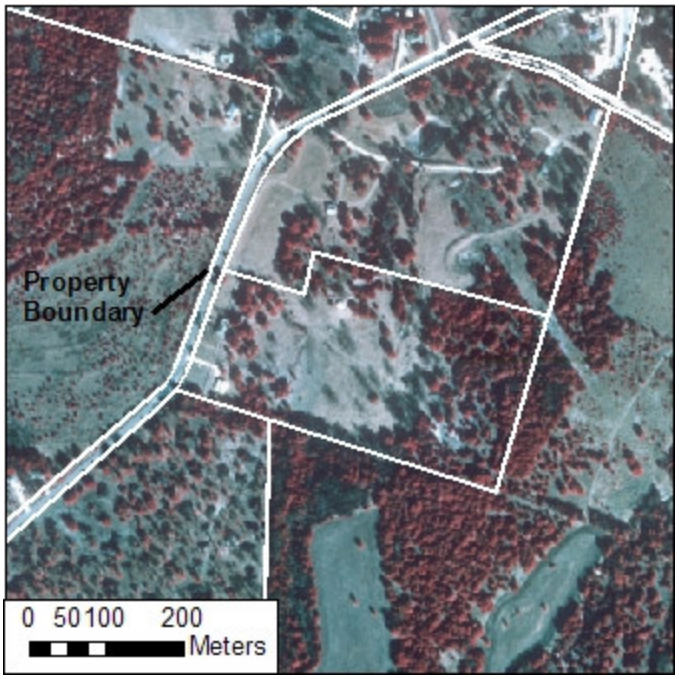

Figure 7. Map showing a zoomed-in portion of the private property boundary layer overlaid on high resolution aerial photography.

Density, Quantity, and Location Analysis of Data Layers

The more significant data layers of the DSGIS are summarized in this section with respect to their density, quantity, and location within the project area. Key attributes of the vegetation, property boundary, ecological sites, and endangered species habitat

layers have been summarized with respect to varying scales including the total project area, county, sub-watershed, and individual landowner tract scale.

Project Area Scale. The project area scale is the largest scale of the DSGIS, and thus provides an overall perspective of the ecological characteristics of the Leon, Lampasas, and Bosque watersheds in Central Texas. The data layers are summarized with respect to their total area and percent coverage within the project area.
The ecological site layer is likely the most important indicator of land use, production potential, and wildlife habitat available within the DSGIS. Ecological sites are important across multiple scales for making land management decisions. The project area consists of 30 different ecological sites; however, about 95% of the total project area is characterized by 15 ecological sites, and about 48% of the project area is characterized by clay loam, shallow, adobe, and low stony hill ecological sites (Table 6). The remaining 5% of the project area consists of 15 different ecological sites, each accounting for 1% or less of the total project area.

The vegetation layer includes four variables that describe the vegetation cover within the DSGIS including juniper, liveoak, deciduous, and no-woody cover. The average juniper cover within the project area is 15%, and the average overall woody cover within the project area is 40% (Table 7). The remaining 1% of the project area that is unaccounted for in Table 7 below is covered by water.

Table 6. Ecological sites found in the project area, and individual and cumulative percentage of the total project area for each.

Ecological Sites Group 1			Ecological Sites Group 2		
Ecological Site	Percent Project Area	Cumulative Percent	Ecological Site	Percent Project Area	Cumulative Percent
Clay Loam	18.9%	19%	Claypan Prairie	1.0%	95%
Shallow	14.8%	34%	Water	1.0%	96%
Adobe	7.2%	41%	Deep Sand	0.8%	97%
Low Stony Hill	7.1%	48%	Chalky Ridge	0.5%	98%
Loamy Sand	6.6%	55%	Shallow Clay	0.4%	98%
Sandy Loam	6.3%	61%	Clay Flat	0.4%	99%
Loamy Bottomland	5.9%	67%	Clayey Bottomland	0.3%	99%
Steep Adobe	5.8%	73%	Steep Rocky	0.3%	100%
Blackland	5.1%	78%	Rocky Hill	0.2%	100%
Stony Clay Loam	4.2%	82%	Sandstone Hill	0.1%	100%
Redland	3.9%	86%	Eroded Blackland	0.1%	100%
Sandy	2.8%	89%	Gravelly	0.0%	100%
Tight Sandy Loam	2.7%	91%	Claypan Savannah	0.0%	100%
Very Shallow	1.9%	93%	Clayey Upland	0.0%	100%
Deep Redland	1.2%	95%	Clay Slopes	0.0%	100%

Table 7. Total area and percent of the project area with juniper, liveoak, deciduous, and non-woody cover.

Vegetation Type	Total Area (ha)	Total Area (ac)	Percent Project Area
Juniper	264,000	652,000	15%
Liveoak	72,000	179,000	4%
Deciduous	366,000	905,000	20%
No Woody	1,076,000	2,658,000	60%

Approximately 94% of the juniper in the project area is located on 10 different ecological sites, and 64% of the juniper is located on shallow, steep adobe, low stony hill, or clay loam sites (Table 8). The 10 ecological sites where the juniper is mostly located makes up 79% of the project area. The juniper is found mostly within the southeastern portions of the project area (Fig. 8). An isolated patch of Redberry Juniper

(*Juniperus pinchotii)* is located in the northern portion of Eastland County; however, the remaining juniper in the project area is primarily Ashe Juniper.

Table 8. Individual percent and cumulative percent of total juniper located on 30 ecological sites in the project area.

Ecological Sites Group 1			Ecological Sites Group 2		
Ecological Site	Percent of Total Juniper	Cumulative Percent of Total Juniper	Ecological Site	Percent of Total Juniper	Cumulative Percent of Total Juniper
Shallow	18.6%	19%	Claypan Prairie	0.3%	99%
Steep Adobe	16.3%	35%	Sandy	0.2%	99%
Low Stony Hill	14.7%	50%	Deep Redland	0.2%	99%
Clay Loam	14.6%	64%	Shallow Clay	0.2%	99%
Adobe	8.9%	73%	Water	0.1%	100%
Loamy Bottomland	4.9%	78%	Clayey Bottomland	0.1%	100%
Stony Clay Loam	4.6%	83%	Eroded Blackland	0.1%	100%
Redland	4.3%	87%	Deep Sand	0.1%	100%
Sandy Loam	3.9%	91%	Rocky Hill	0.1%	100%
Blackland	2.6%	94%	Gravelly	0.1%	100%
Very Shallow	2.2%	96%	Clay Flat	0.1%	100%
Chalky Ridge	0.8%	97%	Sandstone Hill	0.0%	100%
Loamy Sand	0.7%	97%	Claypan Savannah	0.0%	100%
Tight Sandy Loam	0.5%	98%	Clayey Upland	0.0%	100%
Steep Rocky	0.3%	98%	Clay Slopes	0.0%	100%

The location of the juniper within the project area with respect to the land slope is an important consideration for mechanical treatment. The juniper found on slopes greater than 15% is typically too steep for efficient mechanical treatment. Approximately 94% of the juniper in the project area is estimated to be on slopes less than 15% with the remaining juniper on slopes too steep for mechanical treatment (Table 9). Approximately 2% of the project area is characterized by slopes of greater than 15%, while about 6% of the total juniper is found in these areas. This supports the hypothesis

that juniper has historically been confined to steeper slopes and canyons; however, the fact that about 52% of the juniper is located on slopes less than 5% is an indicator that juniper is encroaching from the steeper areas onto adjacent flatter areas.

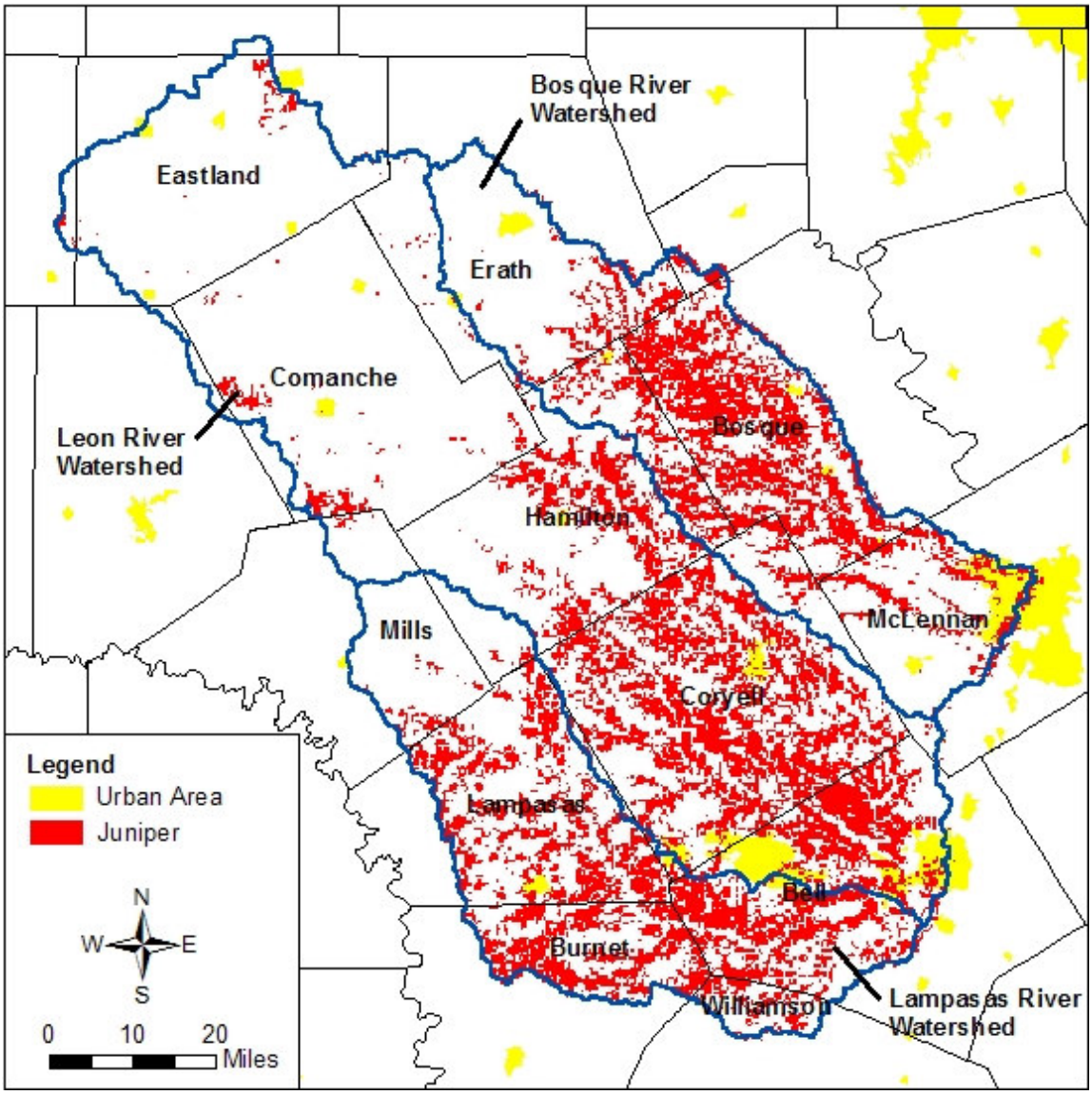

Figure 8. Map showing the juniper cover within the project area.

Table 9. Distribution of the percent slope within the project area and percentage of total juniper cover within 10 different percent slope categories.

Slope Category	Percent Project Area	Cummulative Percent Slope of Project Area	Percent of Total Juniper Cover	Cummulative Percent of Total Juniper Cover
0%-3%	48.9%	48.9%	27.9%	27.9%
3%-5%	25.2%	74.1%	24.3%	52.2%
5%-7%	12.8%	86.8%	17.9%	70.1%
7%-9%	5.9%	92.7%	10.9%	81.0%
9%-11%	2.8%	95.6%	6.4%	87.3%
11%-13%	1.5%	97.1%	3.9%	91.2%
13%-15%	0.9%	98.0%	2.6%	93.8%
15%-17%	0.6%	98.6%	1.8%	95.6%
17%-19%	0.4%	99.0%	1.3%	96.9%
>19%	1.0%	100.0%	3.1%	100.0%

The endangered species habitat layer includes three variables that represent areas of low, moderate, and high potential for golden-cheeked warbler habitat. The majority of the project area is in the low category for golden-cheeked warbler habitat; however, approximately 139,000 total hectares (343,000 acres) and 29,000 total hectares (71,000 acres) are estimated to be adequate for moderate and high potential golden-cheeked warbler habitat, respectively (Table 10).

Table 10. Total area and percent of the project area with high, moderate, and low golden-cheeked warbler habitat potential zones.

GCW[1] Habitat Potential Zone	Total Area (ha)	Total Area (ac)	Percent Project Area
Low	1,624,000	4,012,000	90.7%
Moderate	139,000	343,000	7.7%
High	29,000	71,000	1.6%

[1]GCW=Golden-cheeked warbler

The majority of the golden-cheeked warbler habitat is found in the southeastern portions of the project area, which is consistent with where the juniper is predominately found (Fig. 9).

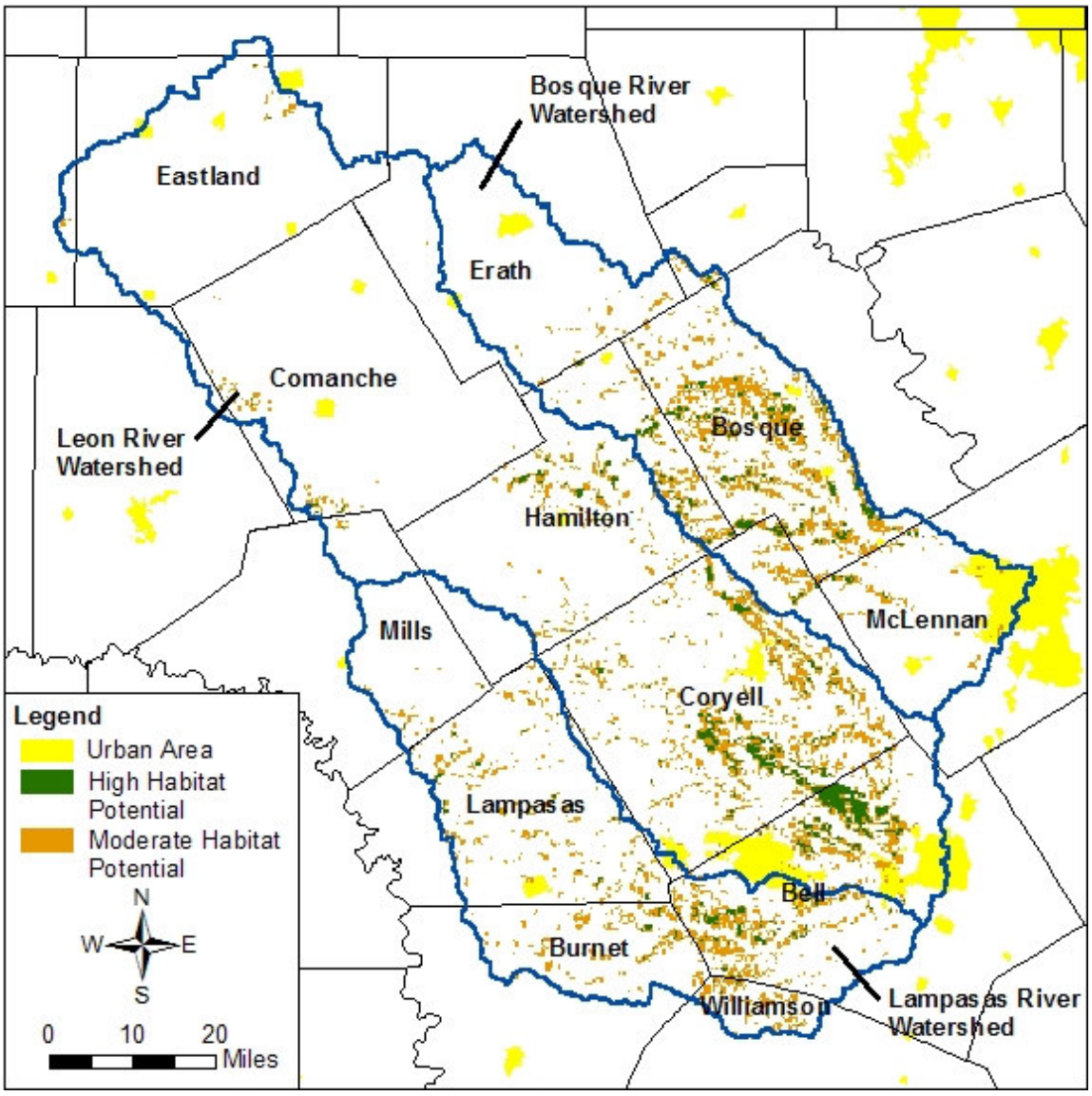

Figure 9. Map showing the high and moderate golden-cheeked warbler habitat potential zones within the project area.

The private property boundary layer was summarized by separating the tract sizes into four categories that most likely represent distinct landowner attributes identified in recent research efforts (see Chapters II and III). The majority of the project area (62%) and portion of landowners within the project area (66%) is represented by tract sizes of 20-202 hectares (50-500 acres) (Table 11). It is interesting to note that approximately 28% of the landowners own less than 20 hectares (50 acres); yet, they only represent about 4% of the total privately owned lands within the project area. In addition, about 34% of the privately owned land is under ownership sizes of greater than 202 hectares (500 acres); yet this area only represents about 6%, or 1,358, of the total landowners. The percentages of the total FSA tract area shown in Table 11 below is representative of the percentage of the total privately owned land with the project area, or the percentage of area with FSA property boundary data only. The military, urban, reservoir, and other lands without FSA data coverage are excluded from the dataset, which represents approximately 14% of the total project area.

Table 11. Total number of landowners, total area, and percent of privately owned project area within tract size categories of < 20 hectares (50 acres), 20-202 hectares (50-500 acres), 202-810 hectares, (500-2,000 acres), and > 810 hectares (2,000 acres).

Tract Size Category	No. of Tracts	Percent of Total Tracts	Total Area (ha)	Total Area (ac)	Percent of Total FSA Tract Area
< 20 ha (< 50 ac)	6,291	28.4%	65,000	160,000	4%
20-202 ha (50-500 ac)	14,531	65.5%	955,000	2,358,000	62%
202-810 ha (500-2,000 ac)	1,271	5.7%	413,000	1,021,000	27%
> 810 ha (> 2,000 ac)	87	0.4%	105,000	260,000	7%
Total:	22,180	100.0%	1,538,000	3,799,000	100%

County Scale. The juniper, golden-cheeked warbler habitat, and landowner property boundary layers were analyzed at the county scale in order to further define the location and density of these layers. A total of 12 counties were identified within the project area for the analysis. The remaining counties were excluded because their proportionate size within the project area is assumed to be insignificant. The juniper layer was analyzed with respect to the area of juniper that would most likely be mechanically treated as part of a large scale brush control program. The juniper located on slopes greater than 15% was excluded from the analysis, which represents about 6% of the total juniper within the project area.

The majority of the juniper within the project area is found within Bosque, Burnet, Bell, and Coryell counties. The average juniper cover for the portion of these counties within the project area is greater than 20% (Table 12).

Table 12. Total area and average percent juniper cover on slopes less than 15% for all or portions of 12 counties within the project area.

County	Percent of County within Project Area	Total Juniper Area[1] (ha)	Total Juniper Area[1] (ac)	Average Percent Juniper Cover[1]
Bell	60%	38,900	96,200	23%
Bosque	55%	37,400	92,400	26%
Burnet	26%	17,400	42,900	25%
Comanche	97%	7,100	17,600	3%
Coryell	100%	57,400	141,900	21%
Eastland	70%	5,000	12,400	3%
Erath	57%	11,200	27,600	7%
Hamilton	100%	28,100	69,500	13%
Lampasas	79%	26,200	64,700	18%
McLennan	35%	9,600	23,800	10%
Mills	39%	2,300	5,600	3%
Williamson	7%	3,400	8,400	16%

[1]Juniper on slopes < 15% only.

Comanche, Eastland, and Mills counties each have an average juniper cover of 3% on slopes less than 15% within the project area.

The total amount of potential golden-cheeked warbler habitat within each of the 12 counties is summarized in Table 13 below. For purposes of the analysis, the moderate and high habitat potential zones were combined to represent the total potential habitat. Bosque county has the highest proportion of potential golden-cheeked warbler habitat at 26% of the total county within the project area. The remaining habitat is mostly concentrated within the portions of Bell, Burnet, Coryell, and Williamson counties within the project area. Comanche, Eastland, Erath, and McLennan, and Mills counties each have an average potential habitat cover of less than 4%.

Table 13. Total area and percentage of moderate and high golden-cheeked warbler potential habitat zones for all or portions of 12 counties within the project area.

County	Percent of County within Project Area	Total Potential GCW[1] Habitat (ha)	Total Potential GCW[1] Habitat (ac)	Average Percent GCW[1] Habitat
Bell	60%	34,600	85,400	20.4%
Bosque	55%	37,200	91,900	25.9%
Burnet	26%	7,100	17,600	10.2%
Comanche	97%	2,300	5,800	1.0%
Coryell	100%	44,200	109,100	16.1%
Eastland	70%	900	2,200	0.5%
Erath	57%	1,800	4,400	1.1%
Hamilton	100%	17,400	43,000	8.0%
Lampasas	79%	11,700	28,900	8.0%
McLennan	35%	3,600	8,800	3.7%
Mills	39%	1,300	3,200	1.7%
Williamson	7%	4,000	9,900	18.8%

[1]GCW = Golden-cheeked warbler

The portion of total privately owned land area and portion of landowners within each of the 12 counties was summarized with respect to four landowner size categories. The majority of the landowners and privately owned land area is found within ownership sizes of 20-202 hectares (50-500 acres) for each of the 12 counties with the exception of Burnet county (Table 14). Approximately 66% of the privately owned portion of Burnet county within the project area is characterized by ownership tracts of greater than 202 hectares (500 acres). Bell, Comanche, and Erath counties have the highest proportion of land area and landowners within the tract size category of less than 20 hectares (50 acres) at greater than 33% of the total landowners and 7% of the total privately owned land area.

Table 14. Percent of total landowners and privately owned county area within tract size categories of < 20 hectares (50 acres), 20-202 hectares (50-500 acres), 202-810 hectares, (500-2,000 acres), and > 810 hectares (2,000 acres).

		Tract Size Category							
		< 20 ha (< 50 ac)		20-202 ha (50-500 ac)		202-810 ha (500-2,000 ac)		> 810 ha (> 2,000 ac)	
	Total No. of	Percent of Total		Percent of Total		Percent of Total		Percent of Total	
County	Tracts	Tracts	Area	Tracts	Area	Tracts	Area	Tracts	Area
Bell	1,771	38%	7%	58%	64%	4%	23%	0%	6%
Bosque	1,471	22%	3%	69%	54%	9%	30%	1%	13%
Burnet	440	13%	1%	64%	33%	22%	48%	2%	18%
Comanche	4,173	38%	7%	59%	69%	3%	20%	0%	4%
Coryell	2,700	27%	4%	67%	65%	6%	28%	0%	3%
Eastland	2,898	26%	5%	71%	75%	3%	17%	0%	3%
Erath	2,739	33%	7%	63%	70%	3%	17%	0%	7%
Hamilton	2,280	18%	2%	73%	60%	8%	30%	1%	8%
Lampasas	1,308	22%	2%	64%	47%	13%	42%	1%	9%
McLennan	1,310	28%	5%	68%	68%	4%	20%	0%	7%
Mills	798	18%	2%	71%	59%	11%	37%	0%	2%
Williamson	292	29%	4%	64%	51%	6%	29%	1%	15%

Sub-Watershed Scale. An analysis of the DSGIS data layers with respect to the sub-watershed scale provides an indication of where the juniper and golden-cheeked warbler habitat are concentrated within the project area. For purposes of this report, the data summarized within each of the sub-watersheds was limited to a graphic representation of the quantity of juniper and golden-cheeked warbler habitat found within each of the 188 total sub-watersheds of the project area. A more detailed listing of the actual land area and percent cover of each of the vegetation types, both the moderate and high golden-cheeked warbler habitat potential zones, and each of the landowner tract size categories can be found in Appendix A. As with the county scale analysis, the juniper located on slopes greater than 15% was excluded from the analysis because it would not likely be included in mechanical treatment in any large scale brush control program.

For the entire project area, the average juniper cover is 15%; however, the juniper cover is concentrated within 12 of the 188 sub-watersheds at an average cover of greater than 30% each (Fig. 10).

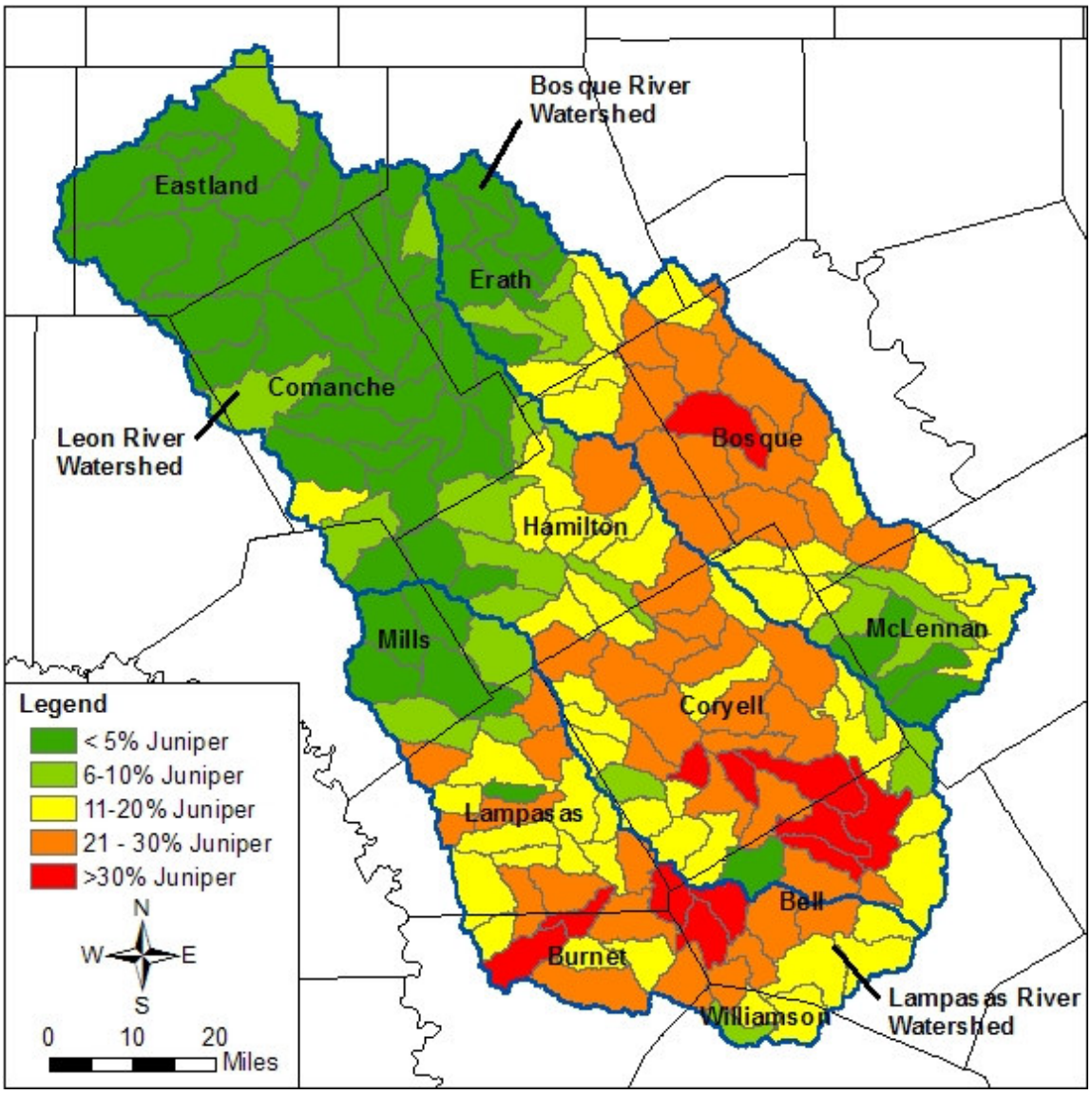

Figure 10. Map showing the average percent juniper cover on slopes less than 15% for 188 sub-watersheds within the project area.

One of these sub-watersheds is located in Bosque county, and the remaining sub-watersheds are located mostly in Coryell, Bell, Lampasas, and Burnet counties. In addition, 44 of the sub-watersheds were identified with an average juniper cover between 21% and 30% on slopes less than 15%.

The golden-cheeked warbler habitat is also concentrated in a selected number of sub-watersheds, with a total land area of greater than 30% found in 17 of the 188 total sub-watersheds (Fig. 11). This compares to an average habitat cover of less than 10% for the entire project area.

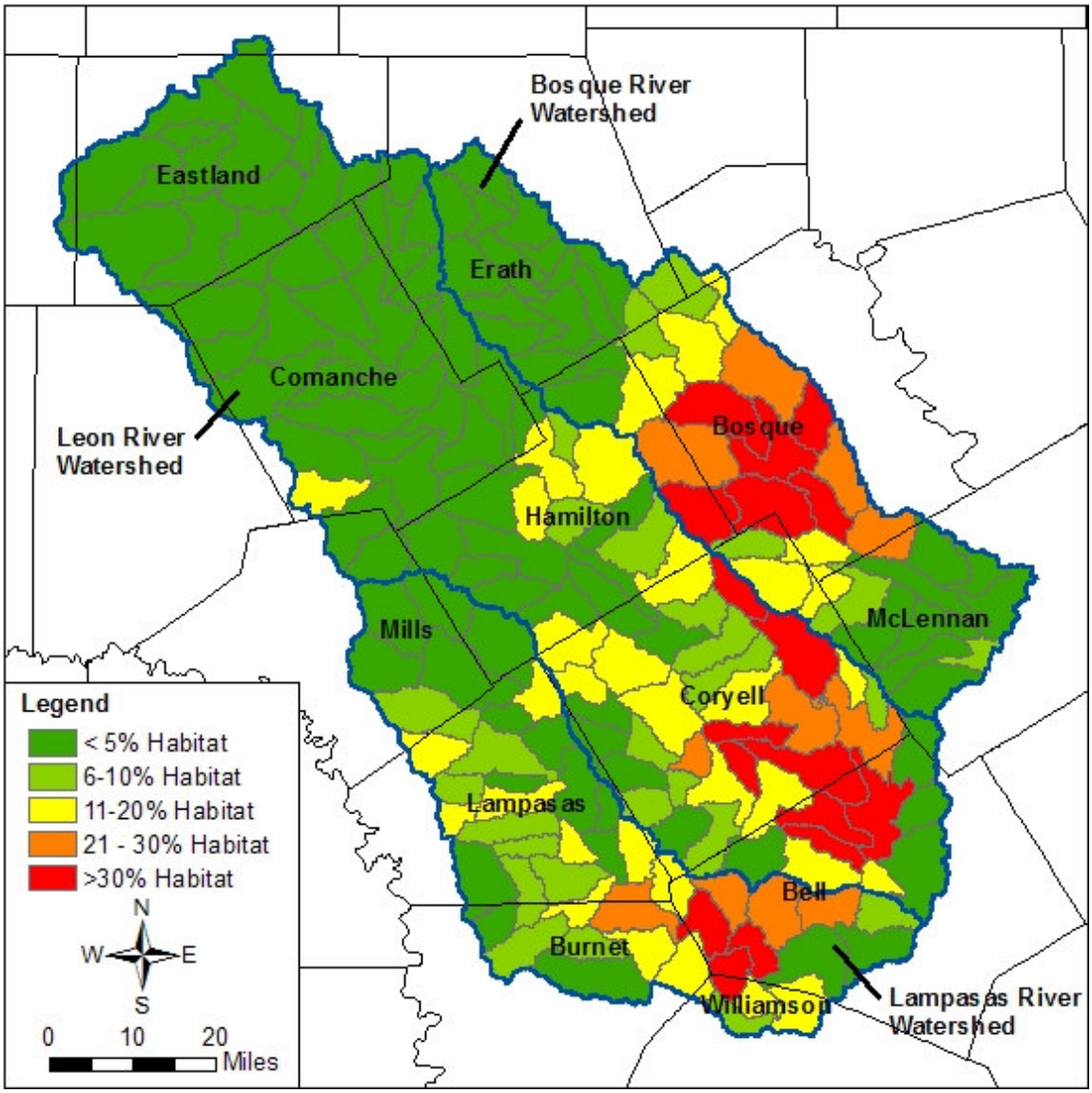

Figure 11. Map showing the percentage of moderate and high golden-cheeked warbler potential habitat zones for 188 sub-watersheds within the project area.

These sub-watersheds are found mostly within Bosque, Coryell, and Bell counties. In addition, 11 of the sub-watersheds were identified with potential golden-cheeked warbler habitat within 21% to 30% of the total land area.

Landowner Tract Scale. The highest resolution where the DSGIS can effectively provide data to support land restoration program decisions is the landowner tract scale. The DSGIS has the capability to quantify the amount and type of vegetation, golden-cheeked warbler habitat, ecological sites, and slopes within each of the property boundaries of the project area. In the following sections, the juniper and golden-cheeked warbler habitat layers where analyzed with respect to their density within the landowner acreage categories as well as their density within individual property boundaries. Similar to the county and sub-watershed analysis, the juniper located on slopes greater than 15% was excluded from the analysis.

The density of juniper, moderate golden-cheeked warbler habitat, and high golden-cheeked warbler habitat within each landowner tract size category was summarized for the project area. The tract size categories match those presented in the project area and county scale analysis above. Although the tract size category of less than 20 hectares (50 acres) represents 28% of the total landowners in the project area, less than 2% of the total juniper and golden-cheeked warbler habitat are found on these lands (Table 15).

Table 15. Proportion of landowners, juniper cover, and golden-cheeked warbler habitat within the project area for tract size categories of < 20 hectares (50 acres), 20-202 hectares (50-500 acres), 202-810 hectares, (500-2,000 acres), and > 810 hectares (2,000 acres).

Tract Size Category	Percent of Total Tracts	Percent of Total Juniper[1]	Percent of Moderate GCW[2] Habitat	Percent of High GCW[2] Habitat
< 20 ha (< 50 ac)	28.4%	2%	1%	1%
20-202 ha (50-500 ac)	65.5%	45%	40%	26%
202-810 ha (500-2,000 ac)	5.7%	26%	30%	24%
> 810 ha (> 2,000 ac)	0.4%	6%	7%	5%
Total:	100.0%	78%	78%	56%

[1]Juniper on slopes < 15% only.

[2]GCW=Golden-cheeked warbler

Alternatively, approximately 32%, 37%, and 29% of the total juniper, moderate golden-cheeked warbler habitat, and high golden-cheeked warbler habitat are respectively found on only 6% of the total properties within the tract sizes of greater than 202 hectares (500 acres). The data indicates that a significant portion (44%) of the high golden-cheeked warbler habitat is not located on privately owned property in the project area. This is in part because a large portion of the golden-cheeked warbler habitat in the project area is located within the Fort Hood military reservation in Coryell and Bell counties. Approximately 22% of the juniper and moderate golden-cheeked warbler habitat also is not found on privately owned lands.

The location of the juniper was also analyzed with respect to the average percent cover found on individual tracts across the project area. This would likely be an important variable for a brush control program that targeted the removal of juniper on privately owned properties. The total amount of juniper across the project area was

quantified using a set of queries that identified tracts within the project area with varying average juniper covers. Approximately 23% of the available juniper is located on tracts at a density of less than 15% average cover. Therefore, this percentage of juniper would not likely be identified as a problem for the landowners and subsequently would likely not be targeted as part of a brush control program (Table 16). Available juniper is defined as the juniper located on slopes less than 15% on privately owned properties and accounts for approximately 74% of the total juniper in the project area. Further analysis of Table 16 indicates that a brush control program that targeted tracts with a minimum average juniper cover of 30% would target about 48% of the total available juniper in the project area and only 11% of the total landowners. Alternatively, a brush control program that targeted tracts with a minimum average juniper cover of 60% would only target approximately 9% of the total available juniper in the project area. The majority of the available juniper in the project area is at a density of less than 60% average cover within the individual tracts.

Table 16. Proportion of landowners and juniper within the project area for categories of > 15%, > 30%, and > 60% percent juniper cover within individual tracts.

Percent Juniper Cover on Slopes < 15% for Individual Tracts	Total No. of Tracts	Percent of Total Tracts	Total Juniper Area[1] (ha)	Total Juniper Area[1] (ac)	Percent of Total Available Juniper[2]
> 15%	4,938	22%	149,000	369,000	77%
> 30%	2,389	11%	94,000	233,000	48%
> 45%	1,190	5%	53,000	130,000	27%
> 60%	424	2%	18,000	44,000	9%

[1]Juniper on slopes < 15% only.

[2]Juniper on slopes < 15% and within FSA property boundaries.

The quantity of potential golden-cheeked warbler habitat within individual tracts was analyzed with respect to the total habitat in the project area. An important variable for a land restoration project that targeted the preservation of golden-cheeked warbler habitat would be the efficiency of habitat preservation for each landowner enrolled in such a program. In other words, landowners with a small quantity of potential habitat would not likely be a candidate for a program versus a landowner with a large portion or acreage of available habitat. The total amount of habitat across the project area was quantified within the DSGIS with a set of queries that identified varying levels of habitat within individual privately owned tracts. Approximately 11% of the total available golden-cheeked warbler habitat is scattered across tracts with less than 8 hectares (20 acres) of high potential habitat or less than 16 hectares (40 acres) of moderate potential habitat (Table 17). The total available habitat is defined as the total moderate and high golden-cheeked warbler habitat on privately owned lands in the project area, which accounts for about 75% of the total habitat in the project area. A habitat preservation program that targeted landowners with a minimum of 32 hectares (80 acres) of high habitat or 65 hectares (160 acres) of moderate habitat would account for 51% of the total available golden-cheeked warbler habitat on privately owned lands. This type of a program would target an estimated 457 total landowners across the project area. In addition, the data indicates that approximately 31 landowners in the project area account for 11% of the total available golden-cheeked warbler habitat on privately owned lands. These landowners have at least 130 hectares (320 acres) of high potential habitat or 259 hectares (640 acres) of moderate potential habitat located within their properties.

Table 17. Total number of tracts, percent of total tracts, total golden-cheeked warbler habitat area, and percent of total golden-cheeked warbler habitat area on privately owned lands within the project area for five categories of total habitat size located within individual tracts.

Golden-Cheeked Warbler (GCW) Habitat on Individual Tracts	Total No. of Tracts	Percent of Total Tracts	Total GCW Habitat Area (ha)	Total GCW Habitat Area (ac)	Percent of Total Available Habitat
> 8 ha (20 ac) High or > 16 ha (40 ac) Moderate Habitat	1,831	8.3%	111,000	274,000	89%
> 16 ha (40 ac) High or > 32 ha (80 ac) Moderate Habitat	1,066	4.8%	93,000	229,000	74%
> 32 ha (80 ac) High or > 65 ha (160 ac) Moderate Habitat	457	2.1%	64,000	157,000	51%
> 65 ha (160 ac) High or > 130 ha (320 ac) Moderate Habitat	144	0.6%	34,000	84,000	27%
> 130 ha (320 ac) High or > 259 ha (640 ac) Moderate Habitat	31	0.1%	13,000	33,000	11%

As described in Chapter III, the FSA property boundary layer includes a FSA tract number for each property boundary. Thus, given the proper clearances from FSA, it would be possible to retrieve the landowner names and contact information of any property of interest from the FSA database. This type of information would be valuable for the implementation and management of a land restoration project.

Analysis of LRRP Costs for Ashe Juniper Treatment

A total of 30 LRRP treatment sites from Years 2002, 2003, and the Spring 2004 were utilized to estimate average treatment costs. Of these 30 sites, seeding cost data

were collected on 6 sites, and compost cost data were collected on 4 sites (Table 18). Composting and seeding work was done only on selected sites that had a low potential for herbaceous response. Follow-up burning has been conducted on several of the sites that were cleared in Year 2002; however, the cost data attributed to the control burns was not available for this analysis.

The average cost across the 30 treatment sites for the juniper clearing and stacking is $583 per hectare ($236 per acre) (Table 18). The sites were cleared using skid steer loaders mounted with hydraulic shears. A machine billing rate of $60.00 per hour was used for the analysis. The average treatment cost is relatively high in comparison with other data and is likely due to the low number of sites used for the analysis. The seeding cost was billed at a flat rate of $56 per hectare ($22.50 per acre), and the composting work cost an average of $79 per hectare ($32 per acre). The total average treatment cost for a site that would require clearing, seeding, and compost is estimated at $717 per hectare ($290 per acre). It is important to note that many of the sites did not require seeding or composting. The large variability in the compost costs is largely due to the type and availability of compost material used at the time of treatment. The low number of sites (4) used to compute the average material cost also attributes to the significance of the variability.

A significant amount of variability also exists in the treatment costs. The treatment costs range from $175 to $1,452 per hectare ($71.00 to $588.00 per acre). This variability is more difficult to explain; however, it is largely due to the range of site and brush conditions that exist across the project area. For example, a few of the sites

have a history of the juniper being cut for cedar posts (posted). The juniper on these sites had re-grown, leaving large stumps in the center of the trees that were difficult for the skid steer loaders to remove. Other site conditions such as the presence of rock, steep slopes, presence of hardwoods mixed with the juniper, and the density of the juniper impacted the clearing cost per acre.

Table 18. Summary of treatment practice costs from the LRRP records and treatment boundaries.

Treatment Practice	Total Sites	Mean	Standard Deviation	Median	95% Confidence Interval
Clearing and Stacking ($/ha)	30	**$583**	$321	$530	$463 - $702
Seeding ($/ha)	6	**$56**	--	--	--
Compost Hauling ($/ha)	4	**$34**	$9	$38	$20 - $49
Compost Material ($/ha)	4	**$45**	$31	$52	($5) - $95
Total Cost ($/ha)		**$717**			

In order to accurately predict the treatment costs of a large scale brush control program, the variability associated with the clearing cost data needed to be further evaluated. A more detailed analysis of the clearing cost data was possible using the information available from the DSGIS data layers. The juniper layer was overlaid on the treatment area boundaries, and a pre-treatment percent cover was estimated for each of the treatment areas. The juniper layer is based on satellite imagery acquired in February and March 2002, which was prior to the clearing work done on the sites. The treatment cost per hectare versus the estimated pre-treatment percent juniper cover was plotted for each of the sites (Fig. 12). This procedure identified 7 of the treatment areas that were major outliers for reasons such as errors in the treatment area boundaries and non-typical

machine work done on the properties on steep slopes. All of the treatment sites had an average pre-treatment juniper cover of less than about 85%, and many of them had an average juniper cover of less than 40%.

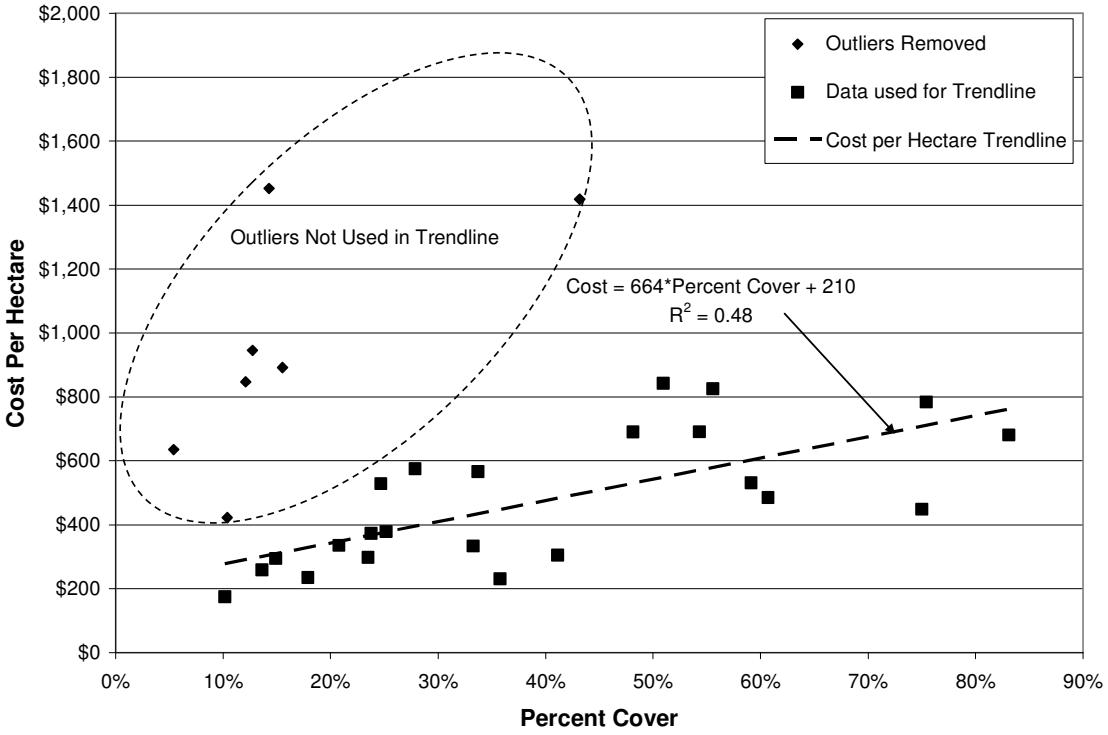

Figure 12. Clearing cost per total treatment area versus total percent cover of juniper within the treatment areas.

A trend line was fitted to the data using a least squares linear regression and illustrates that the unit treatment cost of the sites increases with increasing juniper cover. The regression coefficient for the trend line is 0.48, which suggests that other site conditions are also impacting the treatment costs. The amount of liveoak and deciduous cover as well as the ecological sites that would typically be associated with rocky, steep soils

were also quantified for each of the treatment sites in an attempt to further explain the variability in the treatment cost data. These factors partially explained the variability shown in Figure 12; however, no single factor in addition to the pre-treatment percent cover could be identified as a significant indicator of the variability. This is partly due to the limited number of treatment sites available for the analysis.

As explained in Chapter III, the DSGIS is used to predict the clearing cost of a large scale brush control program based on the predicted area of juniper cleared across a specified geographic area. The quantity of juniper cleared is estimated based on the total number of juniper pixels from the vegetation layer that are located within the area of interest. Each of the juniper pixels represents a 30 meter by 30 meter area of 100% juniper cover. Therefore, it would be inaccurate to apply the average cost per acre shown in Table 18 to the predicted area of juniper cleared from the DSGIS because the value in Table 18 is based on an average juniper cover of less than 100%. As illustrated in Figure 12, the cost to clear a particular site is significantly higher as the juniper cover within the site approaches 100%.

Two methods were analyzed to resolve this issue. First, the average clearing costs for an area of 100% juniper cover were predicted using the juniper layer in the DSGIS overlaid on the treatment area boundaries (100% Juniper Method). The total cost to clear the treatment areas was then divided by the total area of juniper pixels within the boundaries, which results in a cost to clear an area of 100% juniper for the 23 sites included in the analysis. This method resulted in an average cost of $1,354 per hectare ($548 per acre) to clear an area of 100% juniper cover (Table 19).

Table 19. Summary of juniper clearing cost per area of 100% juniper cover using the LRRP treatment boundaries overlaid with the juniper vegetation layer from the DSGIS.

Treatment Practice	Total Sites	Mean	Standard Deviation	Median	95% Confidence Interval
Clearing and Stacking ($/ha)	23	**$1,354**	$466	$1,434	$1,152 - $1,555

The second method for predicting the cost to clear an area of 100% juniper cover is to extrapolate the trend line shown in Figure 12 to a percent cover of 100% (Fitted Line Method). The trend line equation was solved for a percent cover of 100%, which estimates the clearing cost at $874 per hectare ($354 per acre). The estimated clearing cost for 100% juniper using each of the two methods was then multiplied by the total area of juniper pixels within each of the sites and plotted with the original treatment cost data (Fig. 13). Both the 100% Juniper Method and the Fitted Line Method predicted the cost to clear the 23 sites with an average accuracy of 64%.

Further analysis of Figure 13 indicates that the Fitted Line Method underestimates the actual clearing costs percent covers of less than about 35%, and the 100% Juniper Method overestimates the actual clearing costs for percent covers of greater than about 60%. However, the majority of the treatment areas had an average juniper cover of less than 60%. In addition, as indicated in Table 16 above, about 91% of the juniper in the DSGIS project area is at an average density on the of less than 60% cover for each of the ownership tracts. Therefore, the 100% Juniper Method was selected for use in the DSGIS and an average clearing cost of $1,354 per hectare ($548 per acre) of juniper is utilized to predict the costs of a large scale brush control program.

This value is significantly higher than the average treatment costs typically reported; however, it is important to remember that it is based on an area of 100% juniper cover. For a treatment area with 30% juniper cover, the actual clearing and stacking cost is estimated at $406 per hectare ($164 per acre).

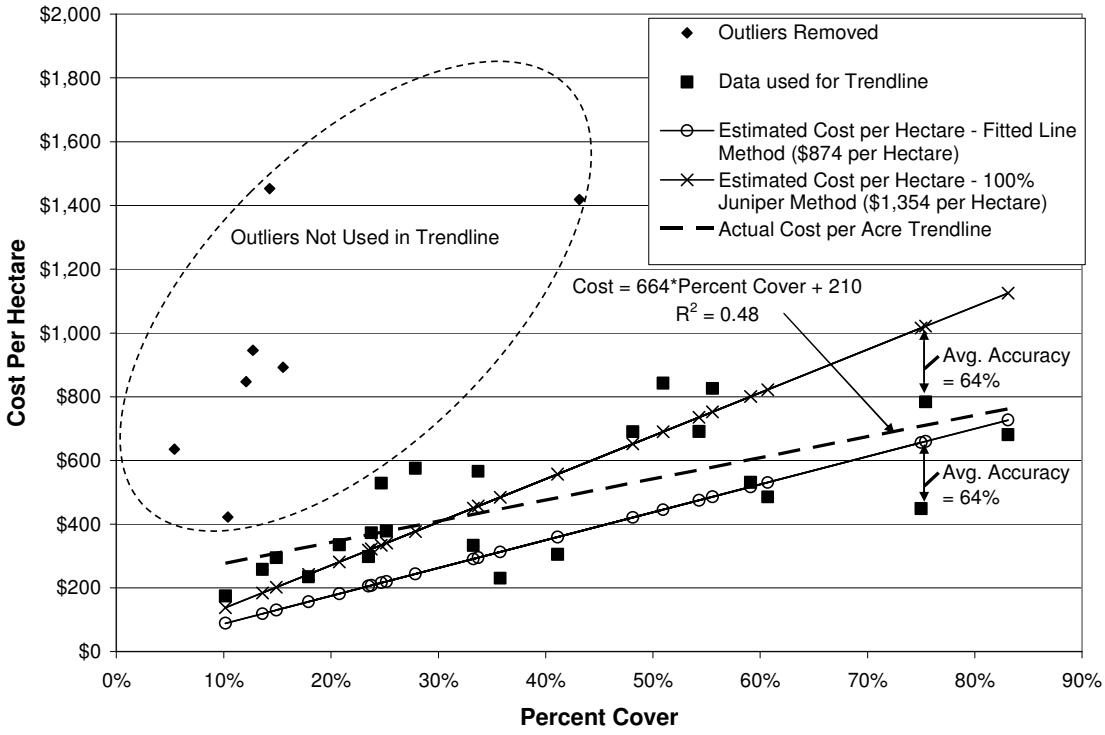

Figure 13. Clearing cost per treatment area versus total percent cover of juniper within the treatment areas. Two methods for estimating the cost per hectare for juniper clearing are included.

Prioritization of Sub-Watersheds, Counties, and Individual Landowner Tracts for Land Restoration Programs

The final objective of the DSGIS is to prioritize and target specific sub-watersheds, counties, and landowner tracts for land restoration programs. A procedure was developed based on the information presented in the above sections, along with recent

research and experience with the LRRP, to prioritize the sub-watersheds within the project area for a publicly funded Ashe Juniper brush control program as well as a golden-cheeked warbler habitat restoration program on privately owned properties. These sub-watershed rankings were then used as a basis for targeting specific counties within the project area. Finally, a procedure for prioritizing specific landowner tracts for a land restoration program is discussed.

The sub-watersheds within the project area were ranked based on four factors that considered the density and locations of the juniper or golden-cheeked warbler habitat as well as the size of the ownership tracts within the sub-watershed. The size of the ownership tracts in the sub-watershed were considered based on the data presented in Tables 11 and 14 above. These data indicate that a land restoration program that targets land ownership sizes of greater that 202 hectares (500 acres) would likely be much more efficient and result in significantly lower administration costs to impact the same amount of land area as a land restoration project targeting smaller landownership sizes. However, this is not to say that other factors should be considered that could impact the long-term investment value of the land restoration program. According to Sanders (2005), smaller landowners may be more interested in the ecological value of a land restoration project, whereas larger landowners may be more interested in the economic value and, therefore, may be less likely to maintain the initial investment over a long term if it is not as economically viable as alternative land uses. In addition, political factors must be considered such as the number of landowners that benefit from using public funds to restore land areas. It may not be politically possible to spend a

significant amount of public funds on a relatively small group of landowners. Nonetheless, for the scenario presented in the following sections, the properties greater than 202 hectares (500 acres) were considered a higher priority than smaller tracts for a land restoration program. The following prioritization scenarios were developed for purposes of demonstrating the capabilities of the DSGIS, and it is important to note that the queries could be modified to meet more specific project needs.

Ashe Juniper Brush Control Program. The sub-watersheds within the project area were prioritized to identify those that would most likely benefit from an Ashe Juniper brush control program. The clearing costs of an Ashe Juniper brush control program for selected sub-watersheds were also estimated using the LRRP treatment cost data presented in the previous section.

The first step in the ranking process was to develop a set of criteria that could be queried from the data layers in the DSGIS and used as ranking factors. The following queries were developed for each of the 188 sub-watersheds:

1. Percent total juniper cover for each sub-watershed.
2. Percent targeted juniper cover for a treatment program within each sub-watershed. This includes the juniper on slopes less than 15% and on landowner properties greater than 20 hectares (50 acres).
3. Percent juniper cover that would likely be preferred by landowners for clearing. This includes the juniper on tracts greater than 20 hectares (50 acres) and with greater than 30% average juniper cover within the individual tracts.

4. Percent of the sub-watershed area with greater than 202 hectare (500 acre) tract sizes.

The first query identifies the sub-watersheds with the most overall juniper cover. The second query in the list above represents the juniper that could potentially be treated within the sub-watershed. The juniper found on slopes greater than 15% is excluded because these slopes are considered too steep for mechanical treatment. In addition, the properties less than 20 hectares (50 acres) were excluded because, as illustrated in Table 15 above, this group of landowners represents 2% of the total available juniper in the project area and accounts for 28% of landowners. It is assumed that this group of landowners would not be considered for an Ashe Juniper brush control program. The third query represents the juniper within the sub-watershed that would be considered a nuisance by the landowners and would therefore most likely be enrolled in a brush control program. Thurow et. al (2000) concluded that landowners in Central Texas preferred an average brush cover of 27% on their properties. It is assumed that the landowners with an average juniper cover of greater than 30% would be more willing to enroll in a brush control program. The final query and ranking factor is used to identify the sub-watersheds that would be result in more efficient brush control programs because a larger geographic area could potentially be impacted with fewer landowners.

The percentages identified with each of the four queries were then summed for each sub-watershed to represent an overall ranking factor. Each of the individual queries, or ranking factors, had an equal weight in the overall ranking factor. For example, a sub-watershed with a value of 50% for each of the four queries would have

an overall ranking factor of 200. The sub-watersheds were then ranked in order from the highest overall ranking factor to the lowest. The top 10 sub-watersheds are presented in Table 20 below. A listing of all of the sub-watersheds along with the four queries used to rank the sub-watersheds is included in Appendix A. The estimated clearing cost for these sub-watersheds ranges from approximately $373,000 for the smallest sub-watershed to $2,281,000 for the largest. This cost is estimated based on the total juniper expected to be cleared from the implementation of a brush control program, which is 32.5% of the total available juniper in the sub-watershed, as explained in Chapter III. A cost of $1,354 per hectare ($548 per acre) is assumed for the unit cost of clearing the juniper, as explained in the preceding section. This cost is for mechanical clearing and stacking only and does not include seeding, composting, follow-up management, or administrative costs. It would, however, be possible with further research to develop a contingency factor for these types of costs.

Table 20. Top 10 sub-watersheds most likely to benefit from an Ashe Juniper brush control program, along with the total area of juniper on tracts greater than 20 hectares (50 acres), the percent juniper expected to be cleared, and the estimated clearing cost for each sub-watershed.

Priority Rank	Sub-Watershed Name	Watershed Size (ha)	Total Available Juniper[1] (ha)	Estimated Juniper Cleared[2] (ha)	Estimated Cost to Clear[3]
1	Upper Mesquite Creek	10,542	3,234	1,051	$ 1,423,188
2	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	7,996	2,321	754	$ 1,021,400
3	Spring Creek	15,384	5,184	1,685	$ 2,281,219
4	Lower Rocky Creek	7,654	1,525	496	$ 670,979
5	East Fork Sulphur and Pillar Bluff Creek	5,121	971	316	$ 427,412
6	Lower East Bosque River (Mustang Creek)	5,252	1,110	361	$ 488,244
7	Upper School Creek	3,694	848	276	$ 373,035
8	Cowhouse Creek Section 4 (Dry and Langford Branch)	11,296	2,736	889	$ 1,203,858
9	Rocky Creek	6,160	1,483	482	$ 652,524
10	Neils Creek Section 2 (Turkey and Shoal Creek)	7,870	2,451	796	$ 1,078,431

[1]Total Available Juniper = Total Juniper within Tracts >20 ha (50 ac)

[2]Estimated Juniper Cleared = Total Available Juniper * 0.325

[3]Estimated Cost to Clear = Estimated Juniper Cleared * $1,354 per ha ($548 per ac)

The location of the top 10 sub-watersheds is shown in Figure 14. Three of the top 10 sub-watersheds identified for an Ashe Juniper brush control program are located in Bosque county and three are located in Burnet county. Several additional sub-watersheds within Coryell and Bell county were identified in Figure 10 above with a high overall percent juniper cover; however, these sub-watersheds were mostly located

within the Fort Hood military reservation and were therefore lower in priority for a brush control program because of the lack of privately owned lands.

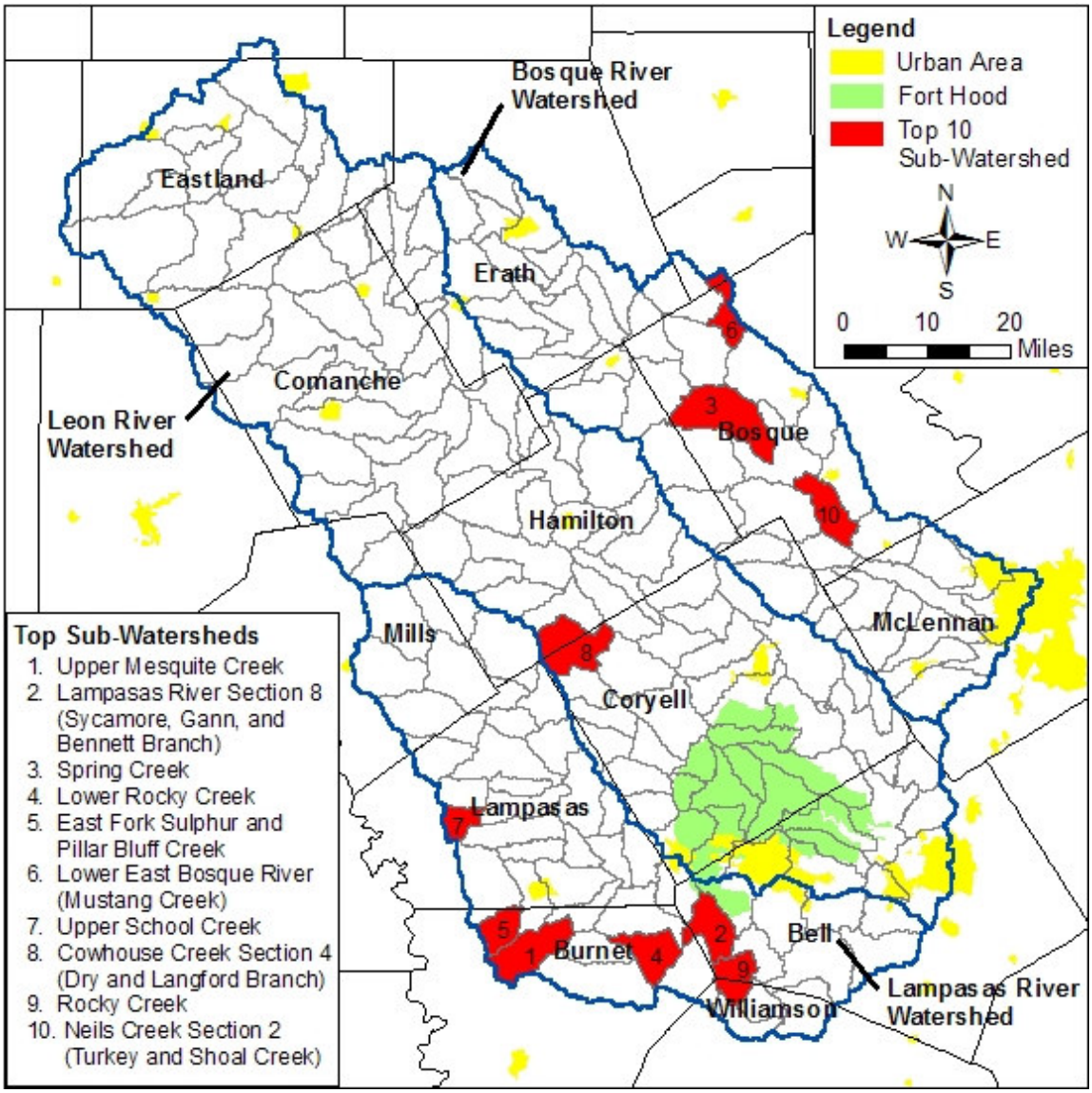

Figure 14. Map identifying the top 10 sub-watersheds most likely to benefit from an Ashe Juniper brush control program.

Golden-cheeked Warbler Habitat Restoration Program. The sub-watersheds within the project area were also prioritized to identify those that would most likely

benefit from a golden-cheeked warbler habitat restoration program. A similar procedure was used to prioritize the sub-watersheds for a golden-cheeked warbler habitat restoration program as explained for the Ashe Juniper brush control program above. The following queries were developed and used as ranking criteria for each of the 188 sub-watersheds:

1. Percent of total moderate and high potential golden-cheeked warbler habitat within each sub-watershed.
2. Percent of total moderate and high potential golden-cheeked warbler habitat on private properties within each sub-watershed.
3. Percent of the sub-watershed area with a minimum of 16 hectares (40 acres) of high potential habitat or 32 hectares (80 acres) of moderate potential habitat within individual landowner tracts.
4. Percent of the sub-watershed area with properties greater than 202 hectare (500 acres).

The moderate and high categories for potential golden-cheeked warbler habitat were combined to represent the total habitat used in the first and second queries. The second query represents the total available golden-cheeked warbler habitat for a restoration program targeting private landowners. It is assumed that smaller landowners would be more willing to enroll in a golden-cheeked warbler habitat restoration program; therefore, tract sizes of less than 20 hectares (50 acres) were included in this analysis, contrary to the criteria for the Ashe Juniper brush control program. The third query represents a minimum patch size for habitat management on private properties.

As described in Chapter II, a Species Biology and Habitat Management Committee formed by the Texas Department of Agriculture recently recommended a minimum conservation unit size of 20 hectares (50 acres) required for golden-cheeked warbler habitat management. The recommended minimum patch size is based on best available research and, for purposes of this study, is assumed to have the requirement of being within a single landowner tract for consideration. In order to differentiate between varying qualities of habitat within the study area, a minimum size of either 16 hectares (40 acres) of high potential habitat or 32 hectares (80 acres) of moderate potential habitat was used in the sub-watershed ranking criteria. As shown in Table 17 above, these criteria exclude approximately 25% of the available habitat on privately owned properties that do not meet the minimum size requirements. The fourth and final query assumes that there would be an economy of scale and a higher efficiency associated with enrolling larger ownership tracts in land restoration projects.

Similar to the process described in the preceding section for an Ashe Juniper brush control program, the percentages obtained from the queries described above were summed to represent an overall ranking factor for each sub-watershed. Each of the queries had an equal weight in the overall ranking factor. The 188 sub-watersheds were then listed in order from the highest to the lowest overall ranking factor. The top 10 sub-watersheds are presented in Table 21 along with the watershed size and the total golden-cheeked warbler habitat available on private property. The estimated amount of available habitat ranges from 777 hectares (1,919 acres) within the smallest sub-

watershed to 5,862 hectares (14,479 acres) within the largest of the top 10 sub-watersheds.

Table 21. Top 10 sub-watersheds most likely to benefit from a golden-cheeked warbler habitat restoration program, along with the total area of moderate and high potential golden-cheeked warbler habitat located on privately owned lands.

Priority Rank	Sub-Watershed Name	Watershed Size (ha)	Total Available Moderate GCW Habitat[1,2] (ha)	Total Available High GCW Habitat[1,2] (ha)	Total Available GCW Habitat[1,2] (ha)
1	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	7,996	2,610	724	3,334
2	Spring Creek	15,384	4,947	915	5,862
3	Rocky Creek	6,160	1,773	228	2,002
4	North Bosque River Section 11 (Dyes and Stanifer Branch; Shumacher Creek)	8,098	2,244	365	2,608
5	Lampasas River Section 9 (Stillman Valley Creek)	5,902	1,250	250	1,500
6	Neils Creek Section 2 (Turkey and Shoal Creek)	7,870	2,088	559	2,647
7	Lower Rocky Creek	7,654	707	70	777
8	Neils Creek Section 1 (Boggy and Jack Branch; Gary Creek)	15,221	3,709	1,122	4,832
9	Upper Neils Creek (Middle Fork Neils and South Fork Neils Creek)	12,603	3,057	618	3,675
10	Lower Coryell Creek	15,375	4,128	572	4,700

[1]GCW = Golden-cheeked warbler

[2]Available GCW Habitat = GCW Habitat on FSA Private Property Boundaries

The location of the top 10 sub-watersheds is shown in Figure 15. Five of the top 10 sub-watersheds identified for a golden-cheeked warbler habitat restoration program are located in Bosque county, and three are located in Bell county. The sub-watershed

identified as 10th on the priority list is Lower Coryell Creek in Coryell county and is also identified as part of the LRRP for the majority of golden-cheeked warbler research currently being conducted.

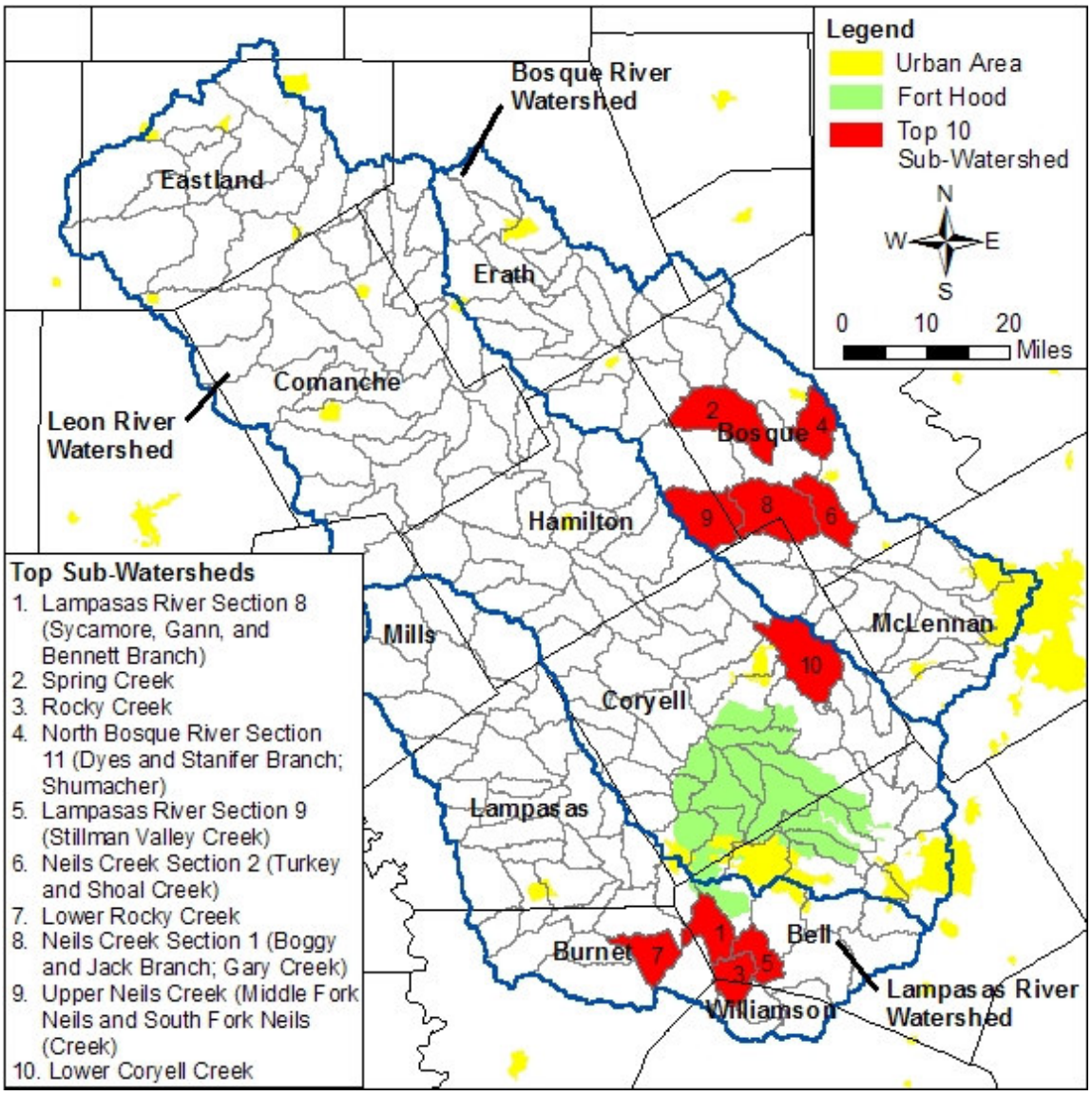

Figure 15. Map identifying the top 10 sub-watersheds most likely to benefit from a golden-cheeked warbler habitat restoration program.

Similar to those sub-watersheds identified for the Ashe Juniper brush control program, several sub-watersheds in Coryell and Bell counties were lower on the priority rankings for a golden-cheeked warbler habitat restoration program because of the location of the Fort Hood military reservation. Although these sub-watersheds have a high quantity of total golden-cheeked warbler habitat, they were ranked lower because of the lack of privately owned lands.

Summary. The sub-watersheds in the DSGIS project area were prioritized separately based on criteria important to an Ashe Juniper brush control and a golden-cheeked warbler habitat restoration program. Nonetheless, some of the sub-watersheds were ranked in the top 10 for both types of restoration projects and would thus be the preferred overall candidates for a land restoration project. These sub-watersheds are as follows, and are listed in no particular order:

- Rocky Creek in Bell and Williamson county.
- Lower Rocky Creek in Burnet county.
- Neils Creek Section 2 (Turkey and Shoal Creek) in Bosque county.
- Spring Creek in Bosque county.

Two of the above sub-watersheds are located in Bosque county as well as three of the top 10 sub-watersheds selected for an Ashe Juniper brush control program and four of the top 10 sub-watersheds selected for a golden-cheeked warbler habitat restoration program. Thus, Bosque county would be the preferred county selected for a land restoration program based on the criteria set forth above.

The DSGIS also has the capability to identify individual landowner tracts for a land restoration project. This would be possible with a query of the database that identified the tracts with a specified quantity or percent cover of juniper or golden-cheeked warbler habitat. In addition, other criteria could be used to fine-tune the query such as distance from the Fort Hood military reservation, location in a certain county or watershed, and property size. The landowner tracts could then be associated with an actual landowner name and contact information using the FSA tract number and the proper clearances from FSA. This type of information is not detailed in this report for reasons of landowner confidentiality as well as the volume of data associated with this type of query.

CHAPTER V

CONCLUSION

The Decision Support Geographic Information System (DSGIS) is a useful tool for policy, planning, and implementation decisions regarding land restoration programs on privately owned rangelands in Central Texas. This chapter includes a brief summary of the DSGIS and its application for land restoration programs, specifically an Ashe juniper brush control program and a golden-cheeked warbler habitat restoration program. A discussion of possible future research that would further enhance the capabilities of the DSGIS and add to the work done thus far is also discussed.

Summary of Results

The spatially referenced data layers and associated database within the DSGIS provide the capability to efficiently and effectively assemble site specific information including vegetation cover, endangered species habitat, landowners, ecological sites, elevation and slope, hydrologic characteristics, and political boundaries. The project area includes approximately 12 counties in Central Texas and is bound by the Leon, Lampasas, and Bosque River watersheds of the Brazos River basin.

The base data layers of the DSGIS were obtained from various government agencies including the Natural Resource Conservation Service (NRCS), Farm Service Agency (FSA), United States Geological Service (USGS), and the United States Census Bureau. Research from the Leon River Restoration Project (LRRP) in Coryell and Hamilton counties was utilized to develop a vegetation cover and golden-cheeked warbler habitat layer from the base data layers for the project area. A landowner

property boundary data layer was developed based on digital FSA property boundary maps that were obtained for 12 of the counties within the project area. The data obtained from the FSA can also be attributed to the efforts of the LRRP, because this level of detailed information would not have been available without the working relationship and cooperation between government agencies that the LRRP has helped to foster.

The vegetation cover data layer was developed by classifying 30-meter resolution satellite imagery and includes juniper, liveoak, deciduous, and non-woody categories. The vegetation layer is estimated to have an overall accuracy of 89% based on field collected vegetation cover data from the LRRP (Holland et al. 2004). The golden-cheeked warbler habitat layer includes high, moderate, and low potential zones for golden-cheeked warbler habitat. This layer was developed based on two separate studies to predict golden-cheeked warbler nesting locations in Bandera county and also in Coryell and Hamilton counties (Magness et al. 2005; Juarez 2004). The accuracy of the golden-cheeked warbler habitat layer is estimated at approximately 61% based on presence/absence surveys conducted as part of the LRRP (Juarez 2004; unpublished data by Tiffany Cummins at Texas A&M University Wildlife and Fisheries Department 2005).

The DSGIS has the capability to provide data analysis and decision support at varying scales including the project area or major watershed, county, sub-watershed, and landowner tract scale. Data from the most significant data layers were summarized at each of these scales. The vegetation data layer indicates that juniper is present on approximately 15% of the total area within the project area, 4% is liveoak, 20% is

deciduous canopy, and 60% of the project area has no woody cover. Most of the juniper can be found in the south and eastern portions of the project area on the Lampasas Cut Plain and Grand Prairie natural regions. Approximately 94% of the juniper is concentrated on 10 of the 30 ecological sites in the project area. The majority of the golden-cheeked warbler habitat is also located on the lampasas cut plain and grand prairie natural regions. Approximately 9.3% of the total project area is classified as either high or moderate potential nesting habitat for golden-cheeked warblers. A large portion of the project area (62%) is characterized by ownership tracts of between 20 and 202 hectares (50 and 500 acres). Approximately 34% of the project area is owned by landowners with greater than 202 hectares (500 acres), and this group accounts for about 6% of the total landowners. The remainder of the project area (4%) is owned by landowners with less than 20 hectares (50 acres), which accounts for about 28% of the landowners.

The proportion of juniper in the project area that is expected to be cleared via a brush control program was analyzed with respect to the density of juniper within individual landowner tracts as well as the expected landowner participation. It is estimated that approximately 23% of the total juniper in the project area is scattered across properties at an average cover of less than 15%, and 52% of the total juniper is located on tracts at an average cover of less than 30%. It is generally accepted that an average brush cover of 30% is optimum for successful wildlife and livestock enterprises, and it was also concluded by Thurrow et al. (2000) that landowners in Central Texas preferred an average of 27% brush cover on their properties. Therefore, a large portion

of the current Ashe Juniper on privately owned properties is likely preferred by landowners and would not be targeted for removal as part of a brush control program. A review of the literature regarding landowner participation in brush control programs concluded that approximately 66.5% of the available Ashe Juniper likely would not be cleared as part of a brush control program. Thus, it is important to target specific sub-regions for an Ashe Juniper brush control program that have high densities of Ashe Juniper and subsequently would likely result in higher landowner participation. The DSGIS provides the ability to identify counties, sub-watersheds, and individual landowner tracts that would most likely benefit from an Ashe Juniper brush control program.

The availability of golden-cheeked warbler habitat in the project area was analyzed with respect to the density of habitat within individual landowner tracts. It is estimated that approximately 74% of the total available habitat in the project area is at a density of either greater than 16 hectares (40 acres) of high potential habitat or greater than 32 hectares (80 acres) of moderate potential habitat on individual tracts. This indicates that the majority of the habitat is located on properties in areas large enough that would likely be effective for restoration and/or preservation efforts. Furthermore, approximately 27%, or 34,000 hectares (84,000 acres) of the total available habitat is located on only 144 properties in the project area.

The project area was sub-divided into 188 sub-watersheds, which were used as a basis to prioritize and target specific regions for Ashe Juniper brush control and golden-cheeked warbler habitat restoration programs. The basis for prioritizing the sub-

watersheds included the total density of juniper or habitat within the sub-watersheds, the location of juniper or habitat with respect to specific sizes and densities within privately owned properties, and the landowner size characteristics of the sub-watersheds. Four ranking factors were developed for each of the sub-watersheds based on the percentage of the respective variable within each sub-watershed. These ranking factors were then summed to represent an overall ranking factor that was used to list the sub-watersheds in priority from 1 to 188 for an Ashe Juniper brush control program and also for a golden-cheeked warbler habitat restoration program. Four of the sub-watersheds were ranked in the top 10 for each of the two land restoration programs, and are as follows:

- Rocky Creek in Bell and Williamson county.
- Lower Rocky Creek in Burnet county.
- Neils Creek Section 2 (Turkey and Shoal Creek) in Bosque county.
- Spring Creek in Bosque county.

These four sub-watersheds, two of which are located in Bosque county, are therefore identified as the most likely to benefit from a land restoration program that involves the control and management of Ashe Juniper and the restoration and/or preservation of golden-cheeked warbler habitat. Sub-watersheds were also identified in Coryell and Lampasas counties that were in the top 10 for the two types of land restoration programs analyzed.

Mechanical treatment of Ashe Juniper is a costly practice, and a successful Ashe Juniper brush control program requires significant public funding to provide cost-share incentives to the landowner for clearing the brush. Therefore, the clearing costs from 23

treatment sites of the LRRP were analyzed and applied to the expected area of Ashe Juniper cleared within the top 10 sub-watersheds identified for an Ashe Juniper brush control program. Based on 23 treatment sites of the LRRP, it is estimated that it costs $1,354 per hectare ($548 per acre) to clear and stack a unit area of 100% juniper cover. For an average juniper cover of 30%, this corresponds to an actual cost of $406 per hectare ($164 per acre). The accuracy of this estimated clearing cost is 64%, and was verified by calculating the pre-treatment juniper cover (using the vegetation layer of the DSGIS) within the treatment area boundaries and then comparing the predicted cost to the actual cost for each of the treatment areas. The top 10 sub-watersheds identified for an Ashe Juniper brush control program ranged in size from 3,698 hectares (9,125 acres) to 15,384 hectares (37,998 acres), and it is estimated that it would cost between $373,000 for the smallest and $2,281,000 for the largest of the sub-watershed to clear the Ashe Juniper. These costs are for 100% of the clearing costs and do not consider the landowner's proportion of a cost-share program. In addition, the costs are based on the assumption that 32.5% of the available juniper in the sub-watershed would be identified for treatment, which is consistent with the expected level of landowner participation.

The data summaries presented as part of this report are merely a snapshot of the overall capabilities of the DSGIS and are based on anticipated decision making criteria of a land restoration program. It is important to note that the specific queries and prioritization criteria can be adjusted to fit more specific needs of many different types of land restoration programs in the project area.

Recommendations for Future Research

There are many opportunities to improve the DSGIS, some of which may include incorporating future research on the impacts and benefits of land restoration programs, refining the costs of land restoration programs, improving the datasets to further enhance the ability to predict landowner participation, and updating the datasets to incorporate changes in vegetation cover, land use, and property boundaries. The framework that has been developed could also be used to support other types of incentive programs such as carbon sequestration.

The ongoing research regarding the benefits of brush control and ecological restoration could be incorporated into the DSGIS to predict site specific responses to varying treatment scenarios. The LRRP research is dedicated to quantifying the hydrologic, wildlife habitat, and livestock production changes associated with the removal and management of Ashe Juniper in relation to ecological sites. This type of information could be readily incorporated into the database of the DSGIS using common ecological sites, and predicted on a larger scale.

An important factor in the planning and implementation of a land restoration program is the expected level of landowner participation. Sanders (2005) identified three types of landowner profiles in Central Texas that displayed differences in their willingness to participate in various natural resource conservation programs. She also indicated that additional research could further refine the ability to profile landowners based on readily available demographic information such as length of tenure, property size, and the location of the landowner's primary residence. This type of data could be

made available from the FSA and incorporated into the DSGIS database using common FSA tract numbers and would greatly enhance the capability of the DSGIS to predict landowner participation on a sub-watershed or county scale.

As with any model or tool, the DSGIS must be updated in order to provide accurate and reliable information. The vegetation cover layer is based on 2002 satellite imagery. The type of satellite imagery used for the analysis is updated annually by the USGS, and could be re-classified to develop an updated vegetation layer. Multiple vegetation layers spaced a few years apart could potentially be used to illustrate the dynamics of the vegetation cover in the project area, such as the rate of encroachment of Ashe Juniper. In addition, the property boundary layer is maintained by the FSA and could also be updated at a minimal cost. It is also important to note that the data layers used as a basis for the DSGIS are readily available for most areas in Texas, and similar types of datasets could be developed at a relatively low cost and timely manner for other regions in Central Texas where ecological restoration on privately owned rangelands is a public interest.

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APPENDIX A

SUB-WATERSHED DATA TABLES

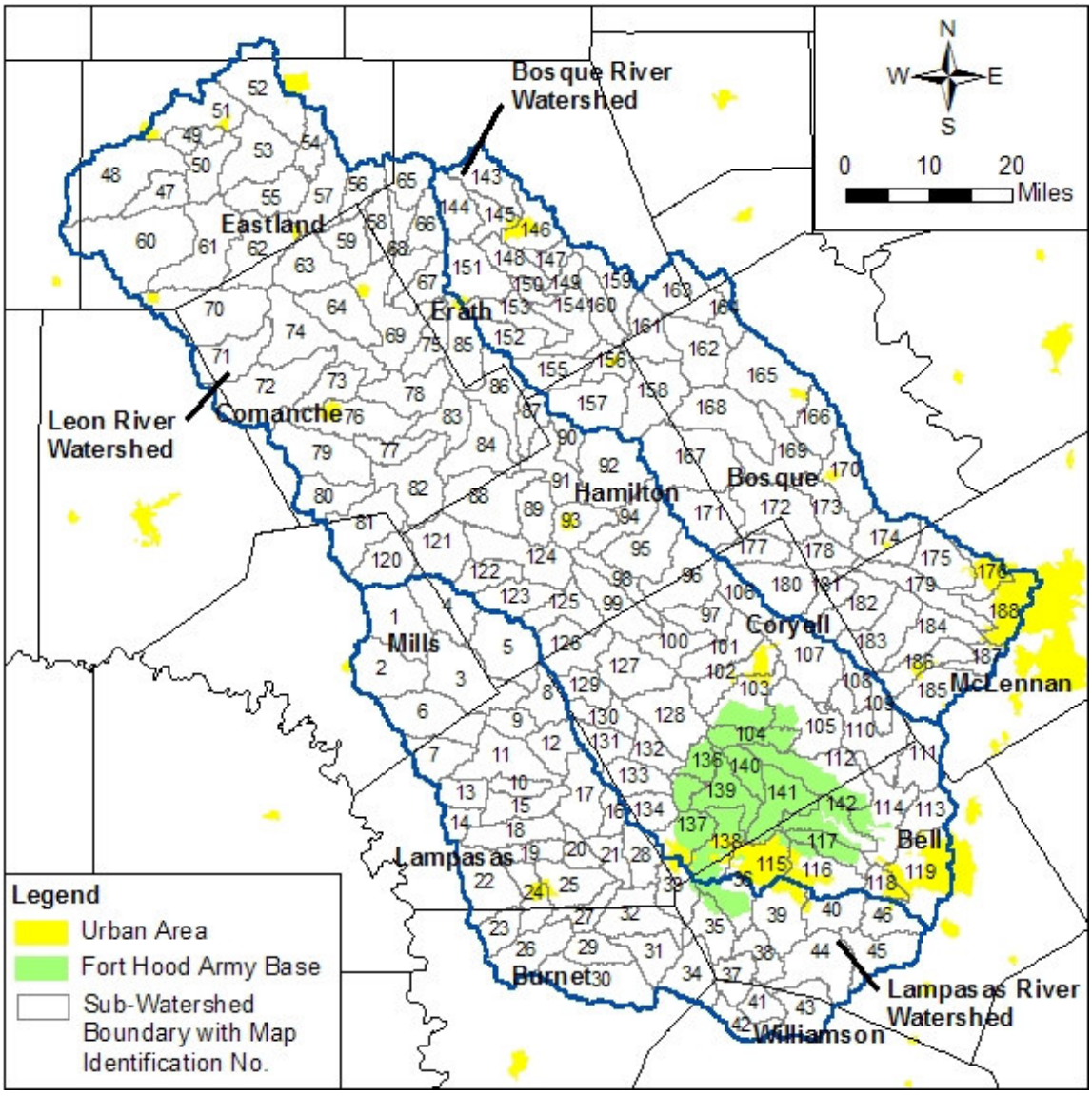

Figure A-1. Map showing the location and identification number of 188 sub-watersheds in the project area

Table A-1. Sub-watersheds listed in order by the Map Identification Number with the sub-watershed name, size, and river watershed name.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
1	North Bennett Creek	Lampasas	13,331
2	South Bennett Creek	Lampasas	12,155
3	Lower Bennett Creek	Lampasas	17,182
4	Upper Lampasas River	Lampasas	11,162
5	Lampasas River Section 2 (Dry Branch)	Lampasas	14,763
6	North Simms Creek	Lampasas	14,335
7	Upper Simms Creek	Lampasas	8,028
8	Lampasas River Section 3 (Heatley and Freeman Branch)	Lampasas	6,672
9	Turkey Creek	Lampasas	4,471
10	Patterson Creek	Lampasas	3,504
11	Lower Simms Creek	Lampasas	12,411
12	Lampasas River Section 4 (Mill Branch)	Lampasas	7,091
13	Barkley Creek	Lampasas	5,185
14	Upper School Creek	Lampasas	3,694
15	Lower School Creek	Lampasas	7,594
16	Fall Creek	Lampasas	3,805
17	Lampasas River Section 5 (Bear and Burleson Branch)	Lampasas	10,883
18	Upper Lucy Creek	Lampasas	8,832
19	Little Lucy Creek	Lampasas	4,472

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
20	Lower Lucy and Road Hollow Creek	Lampasas	3,978
21	Lampasas River Section 6	Lampasas	5,091
22	Donalson and Hughes Creek	Lampasas	12,621
23	East Fork Sulphur and Pillar Bluff Creek	Lampasas	5,121
24	Sulphur Creek Section 1 (Mcnett, Cemetery, and Burleson Creek)	Lampasas	7,266
25	Sulphur Creek Section 2 (Gibson, Gooch, Pecan, and Denson Branch)	Lampasas	9,184
26	Upper Mesquite Creek	Lampasas	10,542
27	Lower Mesquite Creek	Lampasas	5,377
28	Binnion and Taylor Creek	Lampasas	7,030
29	North Rocky Creek	Lampasas	6,221
30	South Rocky Creek	Lampasas	15,761
31	Lower Rocky Creek	Lampasas	7,654
32	Lampasas River Section 7 (Burnet and Panther Den Branch)	Lampasas	11,575
33	Clear Creek	Lampasas	7,579
34	Mill Creek	Lampasas	9,349
35	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	Lampasas	7,996
36	Reese Creek	Lampasas	7,004
37	Rocky Creek	Lampasas	6,160
38	Lampasas River Section 9 (Stillman Valley Creek)	Lampasas	5,902
39	Lampasas River Section 10 (Rock, Onion, and Trimmier Creek; Upper Stillhouse Hollow)	Lampasas	11,274

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
40	Lampasas River Section 11 (Lower Stillhouse Hollow Lake)	Lampasas	7,745
41	Upper Salado Creek	Lampasas	4,532
42	South Salado Creek	Lampasas	5,364
43	Salado Creek Section 1 (Rumsey Creek and Pecan Springs Branch)	Lampasas	10,048
44	Salado Creek Section 2 (Buttermilk and Mustang Creek; Watkins Branch)	Lampasas	14,002
45	Salado Creek Section 3 (Smith, Holland, and Moon Branch)	Lampasas	10,735
46	Lampasas River Section 12 (Mitchell Branch)	Lampasas	6,811
47	Dead Horse Creek	Leon	6,609
48	Upper South Fork Leon River	Leon	22,160
49	Middle Fork Leon River	Leon	4,221
50	Lower South Fork Leon River	Leon	8,087
51	North Fork Leon River	Leon	11,432
52	Colony Creek	Leon	16,717
53	Leon River Section 1 (Lick Branch)	Leon	14,071
54	Leon River Section 2 (Jim Neal Branch)	Leon	5,607
55	Nash Creek	Leon	10,303
56	Hog Creek	Leon	6,021
57	Leon River Section 3 (Salt, Rough, and Ellison Spring Branch)	Leon	11,538
58	Flat Creek	Leon	5,839
59	Leon River Section 4	Leon	7,921

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
60	Upper Sabana River (Yellow and Long Branch)	Leon	26,147
61	Sabana River Section 1 (Elm, Greer, and Hunting Shirt Creek)	Leon	17,066
62	Sabana River Section 2 (Currycomb and Shinoak Branch)	Leon	14,638
63	Sabana River Section 3	Leon	11,289
64	Sabana River Section 4 (Turkey Creek)	Leon	11,244
65	Upper Armstron Creek (East Fork Armstrong Creek)	Leon	7,297
66	Hackberry and Henning Creek	Leon	6,601
67	Cow Creek	Leon	6,534
68	Armstrong Creek Section 1 (Dry Fork and Sand Branch)	Leon	8,453
69	Leon River Section 5 (Proctor Lake)	Leon	16,070
70	Upper Copperas Creek	Leon	20,708
71	South Copperas Creek	Leon	10,143
72	Sweetwater Creek	Leon	19,551
73	Duncan Creek	Leon	6,755
74	Copperas Creek Section 1 (Martins Creek)	Leon	18,225
75	Walnut Creek	Leon	6,604
76	Indian Creek	Leon	14,202
77	Holmsley Creek	Leon	5,658
78	Leon River Section 6 (Mustang and Baggett Creek)	Leon	11,187
79	Mercer Creek	Leon	15,226

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
80	Upper South Leon River	Leon	8,443
81	Mountain Creek	Leon	14,182
82	South Leon River Section 1 (Live Oak and Walnut Creek)	Leon	14,055
83	Leon River Section 7 (Joplin and Mills Creek)	Leon	7,910
84	Leon River Section 8 (Chappell Creek and Bee Branch)	Leon	11,955
85	Upper Resley Creek	Leon	10,566
86	Lower Resley Creek	Leon	11,317
87	Rocky Creek	Leon	5,746
88	Warren Creek	Leon	16,523
89	Bear Creek	Leon	7,559
90	Mesquite Creek	Leon	4,099
91	Leon River Section 9 (Pecan Creek and Alex Branch)	Leon	9,645
92	Leon River Section 10 (Gum Branch; Indian, Little Egg, and Egg Creek)	Leon	16,287
93	Pecan Creek	Leon	7,715
94	Leon River Section 11 (Alexander and Sycamore Creek)	Leon	8,384
95	Leon River Section 12 (Wallace, Orman, and Manning Creek; Beck Branch)	Leon	13,005
96	Leon River Section 13 (Eagle Creek)	Leon	14,158
97	Leon River Section 14	Leon	6,923
98	Mustang Creek	Leon	5,627
99	Upper Plum Creek	Leon	10,814

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
100	Lower Plum Creek	Leon	7,174
101	Leon River Section 15 (Blue and Fourmile Branch)	Leon	9,920
102	Leon River Section 16 (Dodd and Stillhouse Branch)	Leon	9,450
103	Leon River Section 17 (Cottonwood, Shoal, and Turnover Creek)	Leon	10,944
104	Henson Creek	Leon	6,065
105	Leon River Section 18	Leon	13,341
106	Upper Coryell Creek	Leon	6,571
107	Lower Coryell Creek	Leon	15,375
108	Pew Branch	Leon	3,714
109	Station Creek	Leon	3,766
110	Leon River Section 19 (Upper Lake Belton)	Leon	14,047
111	Stampede Creek	Leon	10,251
112	Owl Creek	Leon	14,927
113	Cedar Creek (Lake Belton)	Leon	6,923
114	Leon River Section 20 (Bull Branch; Lower Lake Belton)	Leon	13,706
115	Upper South Nolan Creek	Leon	9,682
116	Lower South Nolan Creek	Leon	10,389
117	North Nolan Creek	Leon	5,594
118	Lower Nolan Creek	Leon	3,752
119	Leon River Section 21 (Pepper and Bird Creek)	Leon	16,353

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
120	Upper Cowhouse Creek	Leon	9,668
121	Cowhouse Creek Section 1 (School Land Creek and Babtist Branch)	Leon	12,219
122	Gholson Creek	Leon	6,317
123	Partridge Creek	Leon	8,123
124	Cowhouse Creek Section 2 (Little Cowhouse Creek)	Leon	13,348
125	Cowhouse Creek Section 3 (Henderson Creek)	Leon	8,021
126	Cowhouse Creek Section 4 (Dry and Langford Branch)	Leon	11,296
127	Cowhouse Creek Section 5 (Bee Creek)	Leon	11,813
128	Cowhouse Creek Section 6 (Riley Branch)	Leon	13,469
129	North Bee House Creek	Leon	5,432
130	Bee House Creek Section 1 (Cromeans and Roberts Creek; Patterson Branch)	Leon	5,951
131	South Bee House Creek	Leon	6,570
132	Lower Bee House Creek	Leon	5,554
133	Table Rock Creek	Leon	7,260
134	Settlement Branch	Leon	6,420
135	Lower Table Rock Creek	Leon	3,134
136	Cowhouse Creek Section 7 (Two Year Old Creek)	Leon	4,188
137	Upper House Creek	Leon	7,772
138	Lower House Creek	Leon	9,364
139	Cowhouse Creek Section 8 (Stampede and Hargrove Creek)	Leon	8,711

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
140	Browns Creek	Leon	4,704
141	Cowhouse Creek Section 9 (Bull Run and Riggs Run; Wolf Creek; Stephenson Branch)	Leon	10,645
142	Cowhouse Creek Section 10 (Oak Branch; Lake Belton)	Leon	8,565
143	North Fork North Bosque River	Bosque	8,708
144	Upper South Fork North Bosque River	Bosque	8,006
145	Lower South Fork North Bosque River	Bosque	4,911
146	North Bosque River Section 1 (Dry and Pole Hollow Branch)	Bosque	8,710
147	North Bosque River Section 2 (Indian Creek)	Bosque	3,983
148	North Bosque River Section 3 (Alarm Creek)	Bosque	5,984
149	North Bosque River Section 4 (Sims Creek)	Bosque	2,982
150	North Bosque River Section 5 (Liveoak Creek)	Bosque	2,682
151	Upper Green Creek	Bosque	10,948
152	Little Green Creek	Bosque	7,023
153	Green Creek Section 1 (Cottonwood Creek and Heavenly Branch)	Bosque	8,349
154	North Bosque River Section 6 (Round Hole Branch and Spring Creek)	Bosque	9,899
155	Gilmore Creek	Bosque	8,110
156	North Bosque River Section 7 (Grubbs Branch)	Bosque	5,239
157	Honey Creek	Bosque	12,534
158	North Bosque River Section 8 (Bailey Branch and Fall Creek)	Bosque	14,214
159	Upper Duffau Creek	Bosque	8,017

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
160	Little Duffau Creek	Bosque	6,360
161	Lower Duffau Creek	Bosque	8,995
162	North Bosque River Section 9 (Walker, Boyd, and Hester Branch)	Bosque	12,202
163	Upper East Bosque River	Bosque	12,333
164	Lower East Bosque River (Mustang Creek)	Bosque	5,252
165	North Bosque River Section 10 (Gibson Branch; Bosque County Reservoir)	Bosque	17,509
166	North Bosque River Section 11 (Dyes and Stanifer Branch; Shumacher Creek)	Bosque	8,098
167	Upper Meridian Creek (North Prong Meridian, South Prong Meridian, and Mustang Cr	Bosque	20,497
168	Spring Creek	Bosque	15,384
169	Meridian Creek Section 1 (Bee Creek)	Bosque	12,573
170	North Bosque River Section 12	Bosque	10,210
171	Upper Neils Creek (Middle Fork Neils and South Fork Neils Creek)	Bosque	12,603
172	Neils Creek Section 1 (Boggy and Jack Branch; Gary Creek)	Bosque	15,221
173	Neils Creek Section 2 (Turkey and Shoal Creek)	Bosque	7,870
174	North Bosque River Section 13 (Rock Springs Creek)	Bosque	10,859
175	North Bosque River Section 14 (Long Branch)	Bosque	9,923
176	North Bosque River Section 15 (Lake Waco)	Bosque	5,848
177	Upper Hog Creek	Bosque	6,585
178	Hog Creek Section 1 (Live Oak Creek)	Bosque	6,687
179	Hog Creek Section 2 (Lake Waco)	Bosque	10,000

Table A-1, cont.

Map Identification No.	Sub-Watershed Name	River Watershed Name	Sub-Watershed Size (ha)
180	Upper Middle Bosque River (Cave Creek)	Bosque	11,575
181	Middle Bosque River Section 1 (Rainey Creek)	Bosque	5,996
182	Middle Bosque River Section 2 (Bluff Creek)	Bosque	11,263
183	Middle Bosque River Section 3 (Wasp and Tonk Creek)	Bosque	12,874
184	Middle Bosque River Section 4 (Pecan Creek; Lake Waco)	Bosque	9,744
185	Upper South Bosque River (Willow Creek)	Bosque	11,666
186	Harris Creek	Bosque	7,742
187	South Bosque River Section 1 (Cloice Creek)	Bosque	4,053
188	Lower Bosque River (Lake Waco)	Bosque	10,538

Table A-2. List of 188 sub-watersheds in the project area with their respective percent juniper cover, high potential golden-cheeked warbler habitat area, moderate potential golden-cheeked warbler habitat area, total potential golden-cheeked warbler habitat area, urban area, and Fort Hood Army base area.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
1	North Bennett Creek	1%	0%	0%	0%	0%	0%
2	South Bennett Creek	2%	1%	0%	1%	0%	0%
3	Lower Bennett Creek	5%	3%	0%	3%	0%	0%
4	Upper Lampasas River	1%	0%	0%	0%	0%	0%
5	Lampasas River Section 2 (Dry Branch)	7%	2%	0%	2%	0%	0%
6	North Simms Creek	11%	6%	0%	6%	0%	0%
7	Upper Simms Creek	26%	13%	2%	15%	0%	0%
8	Lampasas River Section 3 (Heatley and Freeman Branch)	25%	15%	1%	16%	0%	0%
9	Turkey Creek	6%	3%	0%	3%	0%	0%
10	Patterson Creek	4%	1%	0%	1%	0%	0%
11	Lower Simms Creek	16%	9%	0%	9%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
12	Lampasas River Section 4 (Mill Branch)	22%	3%	0%	3%	0%	0%
13	Barkley Creek	16%	8%	2%	10%	0%	0%
14	Upper School Creek	24%	13%	2%	15%	0%	0%
15	Lower School Creek	22%	10%	2%	12%	0%	0%
16	Fall Creek	16%	4%	1%	5%	0%	0%
17	Lampasas River Section 5 (Bear and Burleson Branch)	16%	3%	0%	3%	0%	0%
18	Upper Lucy Creek	17%	8%	0%	8%	0%	0%
19	Little Lucy Creek	19%	7%	0%	7%	0%	0%
20	Lower Lucy and Road Hollow Creek	19%	12%	0%	12%	0%	0%
21	Lampasas River Section 6	17%	3%	0%	3%	0%	0%
22	Donalson and Hughes Creek	16%	3%	0%	3%	0%	0%
23	East Fork Sulphur and Pillar Bluff Creek	19%	2%	0%	2%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
24	Sulphur Creek Section 1 (Mcnett, Cemetery, and Burleson Creek)	24%	7%	0%	7%	0%	15%
25	Sulphur Creek Section 2 (Gibson, Gooch, Pecan, and Denson Branch)	25%	8%	1%	9%	0%	4%
26	Upper Mesquite Creek	31%	8%	0%	8%	0%	0%
27	Lower Mesquite Creek	33%	14%	1%	15%	0%	0%
28	Binnion and Taylor Creek	30%	12%	1%	13%	0%	1%
29	North Rocky Creek	14%	7%	0%	7%	0%	0%
30	South Rocky Creek	26%	5%	0%	5%	0%	0%
31	Lower Rocky Creek	20%	10%	1%	11%	0%	0%
32	Lampasas River Section 7 (Burnet and Panther Den Branch)	26%	20%	3%	23%	0%	0%
33	Clear Creek	34%	16%	1%	17%	5%	9%
34	Mill Creek	25%	13%	0%	13%	0%	0%
35	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	41%	43%	10%	53%	11%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
36	Reese Creek	36%	23%	7%	30%	55%	1%
37	Rocky Creek	31%	37%	4%	41%	0%	0%
38	Lampasas River Section 9 (Stillman Valley Creek)	28%	29%	4%	33%	0%	0%
39	Lampasas River Section 10 (Rock, Onion, and Trimmier Creek; Upper Stillhouse Hollow)	29%	21%	4%	25%	0%	16%
40	Lampasas River Section 11 (Lower Stillhouse Hollow Lake)	33%	23%	4%	27%	0%	6%
41	Upper Salado Creek	16%	19%	0%	19%	0%	0%
42	South Salado Creek	10%	9%	0%	9%	0%	0%
43	Salado Creek Section 1 (Rumsey Creek and Pecan Springs Branch)	13%	13%	0%	13%	0%	0%
44	Salado Creek Section 2 (Buttermilk and Mustang Creek; Watkins Branch)	15%	3%	0%	3%	0%	0%
45	Salado Creek Section 3 (Smith, Holland, and Moon Branch)	14%	1%	0%	1%	0%	0%
46	Lampasas River Section 12 (Mitchell Branch)	19%	6%	1%	7%	0%	3%
47	Dead Horse Creek	1%	0%	0%	0%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
48	Upper South Fork Leon River	2%	0%	0%	0%	0%	1%
49	Middle Fork Leon River	1%	0%	0%	0%	0%	1%
50	Lower South Fork Leon River	1%	0%	0%	0%	0%	0%
51	North Fork Leon River	2%	0%	0%	0%	0%	9%
52	Colony Creek	8%	5%	0%	5%	0%	1%
53	Leon River Section 1 (Lick Branch)	3%	0%	0%	0%	0%	0%
54	Leon River Section 2 (Jim Neal Branch)	1%	0%	0%	0%	0%	0%
55	Nash Creek	1%	0%	0%	0%	0%	0%
56	Hog Creek	4%	0%	0%	0%	0%	0%
57	Leon River Section 3 (Salt, Rough, and Ellison Spring Branch)	1%	0%	0%	0%	0%	1%
58	Flat Creek	3%	0%	0%	0%	0%	0%
59	Leon River Section 4	1%	0%	0%	0%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
60	Upper Sabana River (Yellow and Long Branch)	3%	1%	0%	1%	0%	0%
61	Sabana River Section 1 (Elm, Greer, and Hunting Shirt Creek)	3%	0%	0%	0%	0%	0%
62	Sabana River Section 2 (Currycomb and Shinoak Branch)	3%	0%	0%	0%	0%	2%
63	Sabana River Section 3	2%	0%	0%	0%	0%	0%
64	Sabana River Section 4 (Turkey Creek)	1%	0%	0%	0%	0%	0%
65	Upper Armstron Creek (East Fork Armstrong Creek)	4%	0%	0%	0%	0%	0%
66	Hackberry and Henning Creek	7%	0%	0%	0%	0%	0%
67	Cow Creek	4%	0%	0%	0%	0%	0%
68	Armstrong Creek Section 1 (Dry Fork and Sand Branch)	5%	0%	0%	0%	0%	0%
69	Leon River Section 5 (Proctor Lake)	3%	0%	0%	0%	0%	3%
70	Upper Copperas Creek	3%	0%	0%	0%	0%	2%
71	South Copperas Creek	3%	0%	0%	0%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
72	Sweetwater Creek	7%	4%	0%	4%	0%	0%
73	Duncan Creek	2%	0%	0%	0%	0%	0%
74	Copperas Creek Section 1 (Martins Creek)	1%	0%	0%	0%	0%	0%
75	Walnut Creek	1%	0%	0%	0%	0%	0%
76	Indian Creek	2%	0%	0%	0%	0%	8%
77	Holmsley Creek	3%	0%	0%	0%	0%	0%
78	Leon River Section 6 (Mustang and Baggett Creek)	1%	0%	0%	0%	0%	0%
79	Mercer Creek	3%	0%	0%	0%	0%	0%
80	Upper South Leon River	16%	11%	2%	13%	0%	0%
81	Mountain Creek	7%	3%	0%	3%	0%	0%
82	South Leon River Section 1 (Live Oak and Walnut Creek)	3%	0%	0%	0%	0%	0%
83	Leon River Section 7 (Joplin and Mills Creek)	2%	0%	0%	0%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
84	Leon River Section 8 (Chappell Creek and Bee Branch)	4%	1%	0%	1%	0%	0%
85	Upper Resley Creek	3%	0%	0%	0%	0%	5%
86	Lower Resley Creek	4%	0%	0%	0%	0%	0%
87	Rocky Creek	9%	0%	0%	0%	0%	0%
88	Warren Creek	6%	3%	2%	5%	0%	0%
89	Bear Creek	14%	9%	2%	11%	0%	0%
90	Mesquite Creek	11%	5%	1%	6%	0%	0%
91	Leon River Section 9 (Pecan Creek and Alex Branch)	19%	9%	4%	13%	0%	0%
92	Leon River Section 10 (Gum Branch; Indian, Little Egg, and Egg Creek)	23%	10%	4%	14%	0%	0%
93	Pecan Creek	16%	7%	1%	8%	0%	9%
94	Leon River Section 11 (Alexander and Sycamore Creek)	18%	5%	0%	5%	0%	0%
95	Leon River Section 12 (Wallace, Orman, and Manning Creek; Beck Branch)	18%	6%	0%	6%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
96	Leon River Section 13 (Eagle Creek)	28%	14%	2%	16%	0%	0%
97	Leon River Section 14	24%	5%	1%	6%	0%	0%
98	Mustang Creek	11%	1%	0%	1%	0%	0%
99	Upper Plum Creek	15%	1%	0%	1%	0%	0%
100	Lower Plum Creek	29%	5%	0%	5%	0%	0%
101	Leon River Section 15 (Blue and Fourmile Branch)	23%	6%	1%	7%	0%	0%
102	Leon River Section 16 (Dodd and Stillhouse Branch)	16%	7%	1%	8%	0%	19%
103	Leon River Section 17 (Cottonwood, Shoal, and Turnover Creek)	28%	15%	5%	20%	39%	7%
104	Henson Creek	33%	25%	17%	42%	97%	0%
105	Leon River Section 18	26%	19%	2%	21%	17%	0%
106	Upper Coryell Creek	21%	27%	6%	33%	0%	0%
107	Lower Coryell Creek	23%	28%	4%	32%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
108	Pew Branch	12%	15%	1%	16%	0%	0%
109	Station Creek	9%	9%	0%	9%	0%	0%
110	Leon River Section 19 (Upper Lake Belton)	22%	23%	2%	25%	0%	0%
111	Stampede Creek	8%	1%	0%	1%	0%	1%
112	Owl Creek	44%	21%	24%	45%	63%	0%
113	Cedar Creek (Lake Belton)	11%	4%	0%	4%	0%	1%
114	Leon River Section 20 (Bull Branch; Lower Lake Belton)	37%	25%	15%	40%	18%	2%
115	Upper South Nolan Creek	5%	2%	0%	2%	30%	79%
116	Lower South Nolan Creek	25%	12%	4%	16%	12%	25%
117	North Nolan Creek	45%	37%	8%	45%	80%	0%
118	Lower Nolan Creek	23%	11%	0%	11%	0%	35%
119	Leon River Section 21 (Pepper and Bird Creek)	13%	4%	0%	4%	0%	49%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
120	Upper Cowhouse Creek	1%	0%	0%	0%	0%	0%
121	Cowhouse Creek Section 1 (School Land Creek and Babtist Branch)	2%	0%	0%	0%	0%	0%
122	Gholson Creek	5%	0%	0%	0%	0%	0%
123	Partridge Creek	6%	0%	0%	0%	0%	0%
124	Cowhouse Creek Section 2 (Little Cowhouse Creek)	6%	1%	0%	1%	0%	0%
125	Cowhouse Creek Section 3 (Henderson Creek)	18%	5%	0%	5%	0%	0%
126	Cowhouse Creek Section 4 (Dry and Langford Branch)	26%	12%	1%	13%	0%	0%
127	Cowhouse Creek Section 5 (Bee Creek)	24%	10%	1%	11%	0%	0%
128	Cowhouse Creek Section 6 (Riley Branch)	30%	11%	1%	12%	0%	0%
129	North Bee House Creek	17%	12%	0%	12%	0%	0%
130	Bee House Creek Section 1 (Cromeans and Roberts Creek; Patterson Branch)	18%	3%	0%	3%	0%	0%
131	South Bee House Creek	20%	5%	0%	5%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
132	Lower Bee House Creek	25%	8%	2%	10%	0%	0%
133	Table Rock Creek	9%	2%	0%	2%	0%	0%
134	Settlement Branch	21%	6%	0%	6%	0%	0%
135	Lower Table Rock Creek	18%	7%	1%	8%	89%	0%
136	Cowhouse Creek Section 7 (Two Year Old Creek)	36%	19%	7%	26%	86%	0%
137	Upper House Creek	13%	3%	0%	3%	63%	18%
138	Lower House Creek	19%	7%	1%	8%	91%	20%
139	Cowhouse Creek Section 8 (Stampede and Hargrove Creek)	25%	14%	3%	17%	100%	0%
140	Browns Creek	35%	25%	9%	34%	100%	0%
141	Cowhouse Creek Section 9 (Bull Run and Riggs Run; Wolf Creek; Stephenson Branch)	28%	14%	5%	19%	100%	1%
142	Cowhouse Creek Section 10 (Oak Branch; Lake Belton)	43%	20%	22%	42%	80%	0%
143	North Fork North Bosque River	2%	0%	0%	0%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
144	Upper South Fork North Bosque River	3%	0%	0%	0%	0%	0%
145	Lower South Fork North Bosque River	2%	0%	0%	0%	0%	7%
146	North Bosque River Section 1 (Dry and Pole Hollow Branch)	5%	0%	0%	0%	0%	20%
147	North Bosque River Section 2 (Indian Creek)	3%	0%	0%	0%	0%	0%
148	North Bosque River Section 3 (Alarm Creek)	2%	0%	0%	0%	0%	0%
149	North Bosque River Section 4 (Sims Creek)	6%	0%	0%	0%	0%	0%
150	North Bosque River Section 5 (Liveoak Creek)	3%	0%	0%	0%	0%	0%
151	Upper Green Creek	3%	0%	0%	0%	0%	2%
152	Little Green Creek	3%	0%	0%	0%	0%	0%
153	Green Creek Section 1 (Cottonwood Creek and Heavenly Branch)	7%	2%	0%	2%	0%	1%
154	North Bosque River Section 6 (Round Hole Branch and Spring Creek)	9%	2%	0%	2%	0%	0%
155	Gilmore Creek	13%	4%	1%	5%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
156	North Bosque River Section 7 (Grubbs Branch)	19%	2%	0%	2%	0%	7%
157	Honey Creek	12%	4%	0%	4%	0%	0%
158	North Bosque River Section 8 (Bailey Branch and Fall Creek)	28%	10%	2%	12%	0%	0%
159	Upper Duffau Creek	19%	2%	0%	2%	0%	0%
160	Little Duffau Creek	17%	4%	0%	4%	0%	0%
161	Lower Duffau Creek	28%	9%	0%	9%	0%	0%
162	North Bosque River Section 9 (Walker, Boyd, and Hester Branch)	29%	12%	1%	13%	0%	0%
163	Upper East Bosque River	19%	10%	0%	10%	0%	0%
164	Lower East Bosque River (Mustang Creek)	28%	14%	2%	16%	0%	0%
165	North Bosque River Section 10 (Gibson Branch; Bosque County Reservoir)	25%	24%	3%	27%	0%	3%
166	North Bosque River Section 11 (Dyes and Stanifer Branch; Shumacher Creek)	25%	28%	5%	33%	0%	0%
167	Upper Meridian Creek (North Prong Meridian, South Prong Meridian, and Mustang Cr)	26%	18%	5%	23%	0%	0%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
168	Spring Creek	36%	33%	6%	39%	0%	0%
169	Meridian Creek Section 1 (Bee Creek)	30%	28%	4%	32%	0%	0%
170	North Bosque River Section 12	23%	24%	5%	29%	0%	4%
171	Upper Neils Creek (Middle Fork Neils and South Fork Neils Creek)	28%	27%	6%	33%	0%	0%
172	Neils Creek Section 1 (Boggy and Jack Branch; Gary Creek)	32%	25%	8%	33%	0%	0%
173	Neils Creek Section 2 (Turkey and Shoal Creek)	34%	29%	8%	37%	0%	0%
174	North Bosque River Section 13 (Rock Springs Creek)	28%	24%	4%	28%	0%	2%
175	North Bosque River Section 14 (Long Branch)	17%	3%	0%	3%	0%	2%
176	North Bosque River Section 15 (Lake Waco)	15%	1%	0%	1%	0%	51%
177	Upper Hog Creek	11%	10%	0%	10%	0%	0%
178	Hog Creek Section 1 (Live Oak Creek)	13%	12%	1%	13%	0%	0%
179	Hog Creek Section 2 (Lake Waco)	9%	2%	0%	2%	0%	1%

Table A-2, cont.

Map Identification No.	Sub-Watershed Name	Percent Juniper Cover	Percent Moderate GCW[1] Habitat	Percent High GCW[1] Habitat	Percent Total GCW[1] Habitat	Percent Fort Hood Army Base	Percent Urban
180	Upper Middle Bosque River (Cave Creek)	13%	18%	1%	19%	0%	0%
181	Middle Bosque River Section 1 (Rainey Creek)	16%	13%	5%	18%	0%	0%
182	Middle Bosque River Section 2 (Bluff Creek)	11%	8%	1%	9%	0%	0%
183	Middle Bosque River Section 3 (Wasp and Tonk Creek)	4%	3%	0%	3%	0%	0%
184	Middle Bosque River Section 4 (Pecan Creek; Lake Waco)	8%	1%	0%	1%	0%	1%
185	Upper South Bosque River (Willow Creek)	4%	0%	0%	0%	0%	2%
186	Harris Creek	3%	0%	0%	0%	0%	8%
187	South Bosque River Section 1 (Cloice Creek)	18%	7%	0%	7%	0%	5%
188	Lower Bosque River (Lake Waco)	17%	2%	0%	2%	0%	76%

[1]GCW = golden-cheeked warbler.

Table A-3. List of 188 sub-watersheds in the project area with their respective percent area with FSA data coverage, total number of Farm Service Agency (FSA) tracts, and percent area in four size categories of land ownership tracts.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
1	North Bennett Creek	96%	166	2%	64%	34%	0%
2	South Bennett Creek	95%	171	3%	61%	32%	4%
3	Lower Bennett Creek	98%	185	1%	49%	44%	6%
4	Upper Lampasas River	96%	103	0%	50%	37%	13%
5	Lampasas River Section 2 (Dry Branch)	95%	161	2%	58%	38%	3%
6	North Simms Creek	96%	182	2%	53%	45%	0%
7	Upper Simms Creek	97%	81	1%	53%	43%	3%
8	Lampasas River Section 3 (Heatley and Freeman Branch)	95%	72	1%	49%	50%	0%
9	Turkey Creek	96%	27	0%	20%	35%	45%
10	Patterson Creek	99%	42	1%	64%	35%	0%
11	Lower Simms Creek	99%	122	1%	49%	38%	12%
12	Lampasas River Section 4 (Mill Branch)	91%	75	2%	38%	56%	5%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
13	Barkley Creek	95%	71	3%	66%	14%	17%
14	Upper School Creek	98%	41	2%	34%	33%	31%
15	Lower School Creek	99%	77	0%	39%	61%	0%
16	Fall Creek	98%	38	1%	48%	34%	18%
17	Lampasas River Section 5 (Bear and Burleson Branch)	98%	121	3%	44%	48%	6%
18	Upper Lucy Creek	97%	95	2%	36%	53%	10%
19	Little Lucy Creek	98%	57	2%	46%	51%	0%
20	Lower Lucy and Road Hollow Creek	85%	47	2%	35%	58%	5%
21	Lampasas River Section 6	93%	92	5%	63%	32%	0%
22	Donalson and Hughes Creek	98%	108	2%	35%	42%	21%
23	East Fork Sulphur and Pillar Bluff Creek	99%	38	2%	8%	72%	18%
24	Sulphur Creek Section 1 (Mcnett, Cemetery, and Burleson Creek)	78%	86	4%	32%	62%	1%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
25	Sulphur Creek Section 2 (Gibson, Gooch, Pecan, and Denson Branch)	80%	155	8%	63%	20%	9%
26	Upper Mesquite Creek	99%	78	0%	31%	62%	7%
27	Lower Mesquite Creek	89%	74	4%	53%	39%	4%
28	Binnion and Taylor Creek	78%	87	3%	64%	33%	0%
29	North Rocky Creek	98%	36	1%	15%	25%	59%
30	South Rocky Creek	98%	156	1%	42%	41%	15%
31	Lower Rocky Creek	99%	51	0%	14%	54%	32%
32	Lampasas River Section 7 (Burnet and Panther Den Branch)	94%	142	2%	56%	26%	16%
33	Clear Creek	49%	68	4%	73%	23%	0%
34	Mill Creek	90%	94	2%	36%	62%	0%
35	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	75%	63	3%	38%	29%	30%
36	Reese Creek	33%	33	1%	48%	17%	34%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
37	Rocky Creek	70%	66	3%	45%	51%	2%
38	Lampasas River Section 9 (Stillman Valley Creek)	76%	63	2%	42%	48%	8%
39	Lampasas River Section 10 (Rock, Onion, and Trimmier Creek; Upper Stillhouse Hollow)	70%	139	5%	61%	34%	0%
40	Lampasas River Section 11 (Lower Stillhouse Hollow Lake)	33%	74	5%	80%	15%	0%
41	Upper Salado Creek	96%	69	3%	56%	37%	4%
42	South Salado Creek	92%	103	4%	66%	28%	2%
43	Salado Creek Section 1 (Rumsey Creek and Pecan Springs Branch)	88%	115	4%	34%	15%	47%
44	Salado Creek Section 2 (Buttermilk and Mustang Creek; Watkins Branch)	85%	124	1%	41%	45%	12%
45	Salado Creek Section 3 (Smith, Holland, and Moon Branch)	83%	224	6%	84%	10%	0%
46	Lampasas River Section 12 (Mitchell Branch)	83%	200	14%	77%	9%	0%
47	Dead Horse Creek	99%	167	5%	93%	3%	0%
48	Upper South Fork Leon River	86%	379	4%	81%	15%	0%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
49	Middle Fork Leon River	91%	89	7%	52%	41%	0%
50	Lower South Fork Leon River	97%	157	5%	62%	33%	0%
51	North Fork Leon River	85%	198	5%	74%	13%	8%
52	Colony Creek	85%	267	5%	72%	23%	0%
53	Leon River Section 1 (Lick Branch)	92%	281	6%	68%	19%	7%
54	Leon River Section 2 (Jim Neal Branch)	99%	89	0%	63%	32%	5%
55	Nash Creek	96%	229	5%	83%	12%	0%
56	Hog Creek	88%	137	8%	74%	18%	0%
57	Leon River Section 3 (Salt, Rough, and Ellison Spring Branch)	95%	280	6%	74%	6%	14%
58	Flat Creek	97%	117	4%	75%	21%	0%
59	Leon River Section 4	96%	246	11%	82%	7%	0%
60	Upper Sabana River (Yellow and Long Branch)	90%	501	5%	82%	12%	0%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
61	Sabana River Section 1 (Elm, Greer, and Hunting Shirt Creek)	97%	307	4%	73%	24%	0%
62	Sabana River Section 2 (Currycomb and Shinoak Branch)	84%	234	5%	72%	16%	7%
63	Sabana River Section 3	93%	264	7%	87%	6%	0%
64	Sabana River Section 4 (Turkey Creek)	92%	347	12%	82%	6%	0%
65	Upper Armstron Creek (East Fork Armstrong Creek)	89%	86	2%	50%	36%	12%
66	Hackberry and Henning Creek	97%	141	4%	88%	8%	0%
67	Cow Creek	94%	142	6%	72%	22%	0%
68	Armstrong Creek Section 1 (Dry Fork and Sand Branch)	98%	195	6%	72%	22%	0%
69	Leon River Section 5 (Proctor Lake)	81%	535	18%	73%	9%	0%
70	Upper Copperas Creek	78%	321	4%	77%	7%	11%
71	South Copperas Creek	79%	201	7%	87%	6%	0%
72	Sweetwater Creek	81%	287	5%	64%	25%	5%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
73	Duncan Creek	97%	252	12%	74%	13%	0%
74	Copperas Creek Section 1 (Martins Creek)	92%	552	12%	82%	7%	0%
75	Walnut Creek	89%	134	7%	67%	26%	0%
76	Indian Creek	86%	407	13%	66%	10%	12%
77	Holmsley Creek	98%	146	8%	65%	27%	0%
78	Leon River Section 6 (Mustang and Baggett Creek)	94%	341	11%	75%	14%	0%
79	Mercer Creek	98%	148	1%	49%	30%	20%
80	Upper South Leon River	98%	96	1%	53%	40%	6%
81	Mountain Creek	95%	145	1%	51%	48%	0%
82	South Leon River Section 1 (Live Oak and Walnut Creek)	95%	197	2%	66%	31%	0%
83	Leon River Section 7 (Joplin and Mills Creek)	98%	144	2%	66%	31%	0%
84	Leon River Section 8 (Chappell Creek and Bee Branch)	94%	177	3%	57%	31%	9%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
85	Upper Resley Creek	88%	236	5%	84%	10%	0%
86	Lower Resley Creek	91%	181	3%	74%	18%	4%
87	Rocky Creek	96%	97	3%	68%	23%	6%
88	Warren Creek	96%	186	1%	55%	42%	2%
89	Bear Creek	99%	76	2%	28%	37%	33%
90	Mesquite Creek	97%	69	1%	62%	28%	9%
91	Leon River Section 9 (Pecan Creek and Alex Branch)	99%	137	2%	53%	37%	8%
92	Leon River Section 10 (Gum Branch; Indian, Little Egg, and Egg Creek)	99%	157	1%	48%	36%	15%
93	Pecan Creek	86%	209	14%	65%	21%	0%
94	Leon River Section 11 (Alexander and Sycamore Creek)	99%	134	2%	69%	29%	0%
95	Leon River Section 12 (Wallace, Orman, and Manning Creek; Beck Branch)	98%	156	2%	57%	39%	2%
96	Leon River Section 13 (Eagle Creek)	96%	165	2%	50%	44%	4%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
97	Leon River Section 14	94%	152	8%	75%	16%	0%
98	Mustang Creek	98%	132	3%	84%	13%	0%
99	Upper Plum Creek	98%	156	2%	62%	28%	8%
100	Lower Plum Creek	96%	140	3%	72%	25%	0%
101	Leon River Section 15 (Blue and Fourmile Branch)	98%	150	3%	63%	34%	0%
102	Leon River Section 16 (Dodd and Stillhouse Branch)	88%	186	4%	82%	14%	0%
103	Leon River Section 17 (Cottonwood, Shoal, and Turnover Creek)	48%	170	12%	77%	11%	0%
104	Henson Creek	3%	10	10%	63%	0%	27%
105	Leon River Section 18	86%	228	6%	61%	23%	9%
106	Upper Coryell Creek	98%	110	2%	71%	25%	2%
107	Lower Coryell Creek	96%	236	3%	56%	29%	11%
108	Pew Branch	93%	85	6%	66%	28%	1%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
109	Station Creek	92%	68	5%	48%	25%	23%
110	Leon River Section 19 (Upper Lake Belton)	90%	235	5%	68%	27%	1%
111	Stampede Creek	92%	264	8%	81%	10%	0%
112	Owl Creek	33%	110	6%	77%	17%	0%
113	Cedar Creek (Lake Belton)	87%	229	15%	84%	1%	0%
114	Leon River Section 20 (Bull Branch; Lower Lake Belton)	33%	138	10%	75%	15%	0%
115	Upper South Nolan Creek	18%	74	14%	86%	0%	0%
116	Lower South Nolan Creek	57%	132	9%	68%	23%	0%
117	North Nolan Creek	16%	36	11%	62%	27%	0%
118	Lower Nolan Creek	65%	105	16%	82%	1%	0%
119	Leon River Section 21 (Pepper and Bird Creek)	58%	300	12%	73%	15%	0%
120	Upper Cowhouse Creek	98%	154	2%	80%	18%	0%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
121	Cowhouse Creek Section 1 (School Land Creek and Babtist Branch)	95%	184	2%	78%	21%	0%
122	Gholson Creek	91%	89	2%	61%	36%	0%
123	Partridge Creek	99%	99	1%	62%	24%	13%
124	Cowhouse Creek Section 2 (Little Cowhouse Creek)	98%	209	2%	70%	28%	0%
125	Cowhouse Creek Section 3 (Henderson Creek)	98%	118	2%	56%	19%	24%
126	Cowhouse Creek Section 4 (Dry and Langford Branch)	95%	122	2%	38%	34%	26%
127	Cowhouse Creek Section 5 (Bee Creek)	96%	147	2%	58%	40%	0%
128	Cowhouse Creek Section 6 (Riley Branch)	95%	182	2%	65%	33%	0%
129	North Bee House Creek	98%	96	3%	60%	37%	0%
130	Bee House Creek Section 1 (Cromeans and Roberts Creek; Patterson Branch)	98%	87	1%	68%	31%	0%
131	South Bee House Creek	97%	77	1%	60%	39%	0%
132	Lower Bee House Creek	90%	73	3%	54%	44%	0%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
133	Table Rock Creek	97%	87	1%	66%	32%	1%
134	Settlement Branch	90%	103	4%	70%	11%	15%
135	Lower Table Rock Creek	9%	16	13%	74%	4%	9%
136	Cowhouse Creek Section 7 (Two Year Old Creek)	17%	20	9%	37%	54%	0%
137	Upper House Creek	20%	35	7%	93%	0%	0%
138	Lower House Creek	5%	14	0%	100%	0%	0%
139	Cowhouse Creek Section 8 (Stampede and Hargrove Creek)	0%	0	0%	0%	0%	0%
140	Browns Creek	0%	0	0%	0%	0%	0%
141	Cowhouse Creek Section 9 (Bull Run and Riggs Run; Wolf Creek; Stephenson Branch)	0%	0	0%	0%	0%	0%
142	Cowhouse Creek Section 10 (Oak Branch; Lake Belton)	0%	0	0%	0%	0%	0%
143	North Fork North Bosque River	90%	285	15%	77%	8%	0%
144	Upper South Fork North Bosque River	98%	182	8%	78%	14%	0%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
145	Lower South Fork North Bosque River	91%	129	11%	68%	1%	21%
146	North Bosque River Section 1 (Dry and Pole Hollow Branch)	79%	290	17%	67%	15%	0%
147	North Bosque River Section 2 (Indian Creek)	96%	108	8%	73%	12%	7%
148	North Bosque River Section 3 (Alarm Creek)	97%	203	16%	64%	8%	11%
149	North Bosque River Section 4 (Sims Creek)	98%	77	7%	78%	15%	0%
150	North Bosque River Section 5 (Liveoak Creek)	94%	46	6%	48%	29%	17%
151	Upper Green Creek	95%	319	12%	83%	5%	0%
152	Little Green Creek	98%	88	1%	59%	38%	2%
153	Green Creek Section 1 (Cottonwood Creek and Heavenly Branch)	94%	163	7%	56%	14%	24%
154	North Bosque River Section 6 (Round Hole Branch and Spring Creek)	98%	137	2%	56%	24%	19%
155	Gilmore Creek	98%	131	2%	65%	27%	5%
156	North Bosque River Section 7 (Grubbs Branch)	90%	130	9%	69%	12%	10%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
157	Honey Creek	98%	204	3%	74%	23%	0%
158	North Bosque River Section 8 (Bailey Branch and Fall Creek)	96%	173	2%	57%	33%	8%
159	Upper Duffau Creek	98%	187	5%	79%	15%	1%
160	Little Duffau Creek	95%	137	2%	92%	6%	0%
161	Lower Duffau Creek	93%	123	2%	63%	34%	2%
162	North Bosque River Section 9 (Walker, Boyd, and Hester Branch)	96%	157	4%	53%	14%	30%
163	Upper East Bosque River	71%	50	0%	20%	15%	64%
164	Lower East Bosque River (Mustang Creek)	87%	35	1%	29%	11%	59%
165	North Bosque River Section 10 (Gibson Branch; Bosque County Reservoir)	92%	223	4%	49%	32%	15%
166	North Bosque River Section 11 (Dyes and Stanifer Branch; Shumacher Creek)	97%	82	2%	49%	25%	24%
167	Upper Meridian Creek (North Prong Meridian, South Prong Meridian, and Mustang Cr	94%	244	3%	60%	33%	5%
168	Spring Creek	96%	146	1%	45%	36%	18%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
169	Meridian Creek Section 1 (Bee Creek)	97%	181	3%	59%	23%	15%
170	North Bosque River Section 12	89%	144	3%	60%	35%	3%
171	Upper Neils Creek (Middle Fork Neils and South Fork Neils Creek)	95%	129	1%	57%	42%	0%
172	Neils Creek Section 1 (Boggy and Jack Branch; Gary Creek)	97%	177	1%	60%	39%	0%
173	Neils Creek Section 2 (Turkey and Shoal Creek)	93%	111	2%	59%	39%	0%
174	North Bosque River Section 13 (Rock Springs Creek)	94%	130	2%	55%	40%	2%
175	North Bosque River Section 14 (Long Branch)	80%	110	4%	44%	28%	24%
176	North Bosque River Section 15 (Lake Waco)	53%	122	20%	70%	11%	0%
177	Upper Hog Creek	98%	92	1%	62%	36%	0%
178	Hog Creek Section 1 (Live Oak Creek)	96%	118	3%	74%	23%	0%
179	Hog Creek Section 2 (Lake Waco)	95%	213	5%	79%	17%	0%
180	Upper Middle Bosque River (Cave Creek)	97%	235	5%	66%	26%	3%

Table A-3, cont.

Map ID[1] No.	Sub-Watershed Name	Percent FSA[2] Data Coverage	Total No. of FSA[2] Tracts	Percent Area in Tract Size Category 1[3]	Percent Area in Tract Size Category 2[4]	Percent Area in Tract Size Category 3[5]	Percent Area in Tract Size Category 4[6]
181	Middle Bosque River Section 1 (Rainey Creek)	91%	115	3%	76%	22%	0%
182	Middle Bosque River Section 2 (Bluff Creek)	97%	195	2%	83%	15%	0%
183	Middle Bosque River Section 3 (Wasp and Tonk Creek)	95%	252	4%	81%	15%	0%
184	Middle Bosque River Section 4 (Pecan Creek; Lake Waco)	92%	198	6%	67%	26%	0%
185	Upper South Bosque River (Willow Creek)	93%	164	3%	56%	12%	29%
186	Harris Creek	89%	140	5%	56%	31%	8%
187	South Bosque River Section 1 (Cloice Creek)	77%	83	5%	79%	16%	0%
188	Lower Bosque River (Lake Waco)	30%	109	15%	66%	19%	0%

[1]ID = identification.

[2]FSA = Farm Service Agency.

[3]Tract Size Category 1 = < 20 hectares (50 acres).

[4]Tract Size Category 2 = 20 hectares (50 acres) - 202 hectares (500 acres).

[5]Tract Size Category 3 = 202 hectares (500 acres) - 810 hectares (2,000 acres).

[6]Tract Size Category 4 = > 810 hectares (2,000 acres).

Table A-4. Priority rank of 188 sub-watersheds for an Ashe Juniper brush control program based on four ranking factors.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
1	26	Upper Mesquite Creek	31%	31%	21%	69%	152%
2	35	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	41%	28%	22%	59%	151%
3	168	Spring Creek	36%	32%	28%	54%	150%
4	31	Lower Rocky Creek	20%	19%	10%	86%	136%
5	23	East Fork Sulphur and Pillar Bluff Creek	19%	19%	7%	90%	135%
6	164	Lower East Bosque River (Mustang Creek)	28%	21%	6%	70%	125%
7	14	Upper School Creek	24%	22%	14%	64%	124%
8	126	Cowhouse Creek Section 4 (Dry and Langford Branch)	26%	23%	16%	60%	124%
9	37	Rocky Creek	31%	23%	17%	53%	124%
10	173	Neils Creek Section 2 (Turkey and Shoal Creek)	34%	27%	23%	39%	123%
11	30	South Rocky Creek	26%	25%	16%	56%	123%
12	34	Mill Creek	25%	22%	14%	62%	123%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
13	27	Lower Mesquite Creek	32%	26%	21%	43%	123%
14	172	Neils Creek Section 1 (Boggy and Jack Branch; Gary Creek)	32%	28%	22%	39%	121%
15	96	Leon River Section 13 (Eagle Creek)	28%	25%	19%	48%	120%
16	29	North Rocky Creek	14%	13%	8%	84%	119%
17	38	Lampasas River Section 9 (Stillman Valley Creek)	28%	21%	14%	56%	119%
18	162	North Bosque River Section 9 (Walker, Boyd, and Hester Branch)	29%	27%	18%	44%	118%
19	24	Sulphur Creek Section 1 (Mcnett, Cemetery, and Burleson Creek)	24%	19%	12%	63%	118%
20	163	Upper East Bosque River	19%	12%	5%	79%	116%
21	7	Upper Simms Creek	26%	24%	18%	46%	114%
22	15	Lower School Creek	22%	21%	10%	61%	114%
23	169	Meridian Creek Section 1 (Bee Creek)	30%	24%	21%	38%	113%
24	12	Lampasas River Section 4 (Mill Branch)	22%	18%	10%	61%	111%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
25	174	North Bosque River Section 13 (Rock Springs Creek)	28%	22%	18%	42%	111%
26	158	North Bosque River Section 8 (Bailey Branch and Fall Creek)	28%	25%	17%	41%	110%
27	128	Cowhouse Creek Section 6 (Riley Branch)	30%	26%	21%	33%	110%
28	92	Leon River Section 10 (Gum Branch; Indian, Little Egg, and Egg Creek)	23%	22%	14%	51%	110%
29	166	North Bosque River Section 11 (Dyes and Stanifer Branch; Shumacher Creek)	25%	20%	15%	49%	109%
30	8	Lampasas River Section 3 (Heatley and Freeman Branch)	25%	21%	13%	50%	109%
31	171	Upper Neils Creek (Middle Fork Neils and South Fork Neils Creek)	28%	24%	14%	42%	108%
32	132	Lower Bee House Creek	25%	21%	18%	44%	108%
33	89	Bear Creek	14%	13%	9%	70%	106%
34	32	Lampasas River Section 7 (Burnet and Panther Den Branch)	26%	23%	14%	42%	106%
35	165	North Bosque River Section 10 (Gibson Branch; Bosque County Reservoir)	25%	19%	14%	47%	105%
36	161	Lower Duffau Creek	28%	25%	15%	36%	104%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
37	136	Cowhouse Creek Section 7 (Two Year Old Creek)	36%	7%	7%	54%	103%
38	22	Donalson and Hughes Creek	16%	15%	10%	63%	103%
39	36	Reese Creek	36%	9%	7%	51%	103%
40	18	Upper Lucy Creek	17%	16%	7%	63%	102%
41	167	Upper Meridian Creek (North Prong Meridian, South Prong Meridian, and Mustang Cr	26%	21%	16%	38%	101%
42	39	Lampasas River Section 10 (Rock, Onion, and Trimmier Creek; Upper Stillhouse Hollow)	29%	19%	18%	34%	100%
43	20	Lower Lucy and Road Hollow Creek	19%	13%	3%	63%	99%
44	100	Lower Plum Creek	29%	27%	17%	25%	98%
45	19	Little Lucy Creek	19%	18%	9%	51%	98%
46	28	Binnion and Taylor Creek	30%	20%	14%	33%	97%
47	127	Cowhouse Creek Section 5 (Bee Creek)	24%	21%	11%	40%	96%
48	107	Lower Coryell Creek	23%	19%	13%	40%	95%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
49	16	Fall Creek	16%	16%	10%	52%	94%
50	17	Lampasas River Section 5 (Bear and Burleson Branch)	16%	15%	7%	54%	93%
51	9	Turkey Creek	6%	6%	1%	80%	93%
52	33	Clear Creek	34%	18%	17%	23%	92%
53	91	Leon River Section 9 (Pecan Creek and Alex Branch)	19%	17%	10%	45%	92%
54	43	Salado Creek Section 1 (Rumsey Creek and Pecan Springs Branch)	13%	11%	4%	62%	91%
55	105	Leon River Section 18	26%	20%	13%	32%	91%
56	170	North Bosque River Section 12	23%	17%	12%	38%	90%
57	101	Leon River Section 15 (Blue and Fourmile Branch)	23%	20%	11%	34%	88%
58	125	Cowhouse Creek Section 3 (Henderson Creek)	18%	17%	10%	43%	88%
59	44	Salado Creek Section 2 (Buttermilk and Mustang Creek; Watkins Branch)	15%	12%	4%	57%	87%
60	11	Lower Simms Creek	16%	15%	6%	50%	87%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
61	175	North Bosque River Section 14 (Long Branch)	17%	12%	5%	52%	86%
62	95	Leon River Section 12 (Wallace, Orman, and Manning Creek; Beck Branch)	18%	17%	8%	41%	85%
63	80	Upper South Leon River	16%	14%	9%	46%	84%
64	131	South Bee House Creek	20%	17%	8%	39%	83%
65	106	Upper Coryell Creek	21%	19%	14%	27%	81%
66	41	Upper Salado Creek	16%	15%	6%	41%	79%
67	25	Sulphur Creek Section 2 (Gibson, Gooch, Pecan, and Denson Branch)	25%	16%	8%	29%	78%
68	110	Leon River Section 19 (Upper Lake Belton)	22%	16%	10%	28%	77%
69	129	North Bee House Creek	17%	13%	9%	37%	76%
70	134	Settlement Branch	21%	17%	12%	26%	75%
71	130	Bee House Creek Section 1 (Cromeans and Roberts Creek; Patterson Branch)	18%	17%	10%	31%	75%
72	117	North Nolan Creek	45%	3%	0%	27%	75%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
73	94	Leon River Section 11 (Alexander and Sycamore Creek)	18%	17%	9%	29%	74%
74	40	Lampasas River Section 11 (Lower Stillhouse Hollow Lake)	33%	11%	13%	15%	73%
75	112	Owl Creek	44%	7%	5%	17%	73%
76	21	Lampasas River Section 6	17%	15%	7%	32%	71%
77	99	Upper Plum Creek	15%	14%	5%	36%	70%
78	6	North Simms Creek	11%	10%	4%	45%	69%
79	13	Barkley Creek	16%	14%	8%	31%	69%
80	97	Leon River Section 14	24%	19%	10%	16%	69%
81	116	Lower South Nolan Creek	25%	11%	7%	23%	66%
82	114	Leon River Section 20 (Bull Branch; Lower Lake Belton)	37%	8%	6%	15%	66%
83	156	North Bosque River Section 7 (Grubbs Branch)	19%	16%	9%	22%	66%
84	109	Station Creek	9%	7%	1%	48%	64%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
85	81	Mountain Creek	7%	6%	3%	48%	64%
86	154	North Bosque River Section 6 (Round Hole Branch and Spring Creek)	9%	8%	2%	43%	62%
87	155	Gilmore Creek	13%	12%	6%	32%	62%
88	90	Mesquite Creek	11%	10%	4%	37%	61%
89	104	Henson Creek	33%	1%	0%	27%	61%
90	177	Upper Hog Creek	11%	10%	4%	36%	60%
91	103	Leon River Section 17 (Cottonwood, Shoal, and Turnover Creek)	28%	12%	9%	11%	60%
92	159	Upper Duffau Creek	19%	17%	8%	16%	60%
93	88	Warren Creek	6%	6%	4%	44%	60%
94	3	Lower Bennett Creek	5%	4%	0%	50%	59%
95	180	Upper Middle Bosque River (Cave Creek)	13%	11%	6%	29%	59%
96	181	Middle Bosque River Section 1 (Rainey Creek)	16%	12%	7%	22%	57%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
97	5	Lampasas River Section 2 (Dry Branch)	7%	6%	2%	41%	56%
98	65	Upper Armstron Creek (East Fork Armstrong Creek)	4%	4%	0%	48%	56%
99	79	Mercer Creek	3%	3%	0%	50%	55%
100	93	Pecan Creek	16%	12%	7%	21%	55%
101	187	South Bosque River Section 1 (Cloice Creek)	18%	13%	8%	16%	55%
102	108	Pew Branch	12%	10%	3%	29%	54%
103	133	Table Rock Creek	9%	8%	4%	33%	53%
104	4	Upper Lampasas River	1%	1%	0%	50%	52%
105	178	Hog Creek Section 1 (Live Oak Creek)	13%	12%	3%	23%	51%
106	153	Green Creek Section 1 (Cottonwood Creek and Heavenly Branch)	7%	5%	1%	38%	51%
107	150	North Bosque River Section 5 (Liveoak Creek)	3%	2%	0%	46%	51%
108	42	South Salado Creek	10%	9%	1%	30%	50%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
109	157	Honey Creek	12%	11%	4%	23%	49%
110	123	Partridge Creek	6%	6%	1%	37%	49%
111	185	Upper South Bosque River (Willow Creek)	4%	3%	0%	41%	49%
112	102	Leon River Section 16 (Dodd and Stillhouse Branch)	16%	12%	7%	14%	49%
113	46	Lampasas River Section 12 (Mitchell Branch)	19%	13%	7%	9%	48%
114	84	Leon River Section 8 (Chappell Creek and Bee Branch)	4%	3%	0%	40%	47%
115	87	Rocky Creek	9%	8%	1%	29%	47%
116	122	Gholson Creek	5%	5%	1%	36%	46%
117	152	Little Green Creek	3%	3%	0%	40%	46%
118	10	Patterson Creek	4%	4%	1%	35%	44%
119	160	Little Duffau Creek	17%	15%	6%	6%	44%
120	186	Harris Creek	3%	2%	0%	39%	44%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
121	142	Cowhouse Creek Section 10 (Oak Branch; Lake Belton)	43%	0%	0%	0%	43%
122	72	Sweetwater Creek	7%	5%	1%	30%	43%
123	49	Middle Fork Leon River	1%	1%	0%	41%	43%
124	118	Lower Nolan Creek	23%	11%	8%	1%	42%
125	184	Middle Bosque River Section 4 (Pecan Creek; Lake Waco)	8%	6%	2%	26%	42%
126	124	Cowhouse Creek Section 2 (Little Cowhouse Creek)	6%	6%	1%	28%	41%
127	45	Salado Creek Section 3 (Smith, Holland, and Moon Branch)	14%	11%	5%	10%	40%
128	2	South Bennett Creek	2%	2%	0%	36%	40%
129	54	Leon River Section 2 (Jim Neal Branch)	1%	1%	0%	37%	40%
130	98	Mustang Creek	11%	9%	7%	13%	39%
131	52	Colony Creek	8%	7%	1%	23%	39%
132	188	Lower Bosque River (Lake Waco)	17%	1%	0%	19%	38%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
133	182	Middle Bosque River Section 2 (Bluff Creek)	11%	9%	3%	15%	38%
134	82	South Leon River Section 1 (Live Oak and Walnut Creek)	3%	3%	0%	31%	36%
135	179	Hog Creek Section 2 (Lake Waco)	9%	8%	1%	17%	36%
136	1	North Bennett Creek	1%	1%	0%	34%	35%
137	50	Lower South Fork Leon River	1%	1%	0%	33%	35%
138	140	Browns Creek	35%	0%	0%	0%	35%
139	119	Leon River Section 21 (Pepper and Bird Creek)	13%	5%	1%	15%	34%
140	83	Leon River Section 7 (Joplin and Mills Creek)	2%	2%	0%	31%	34%
141	77	Holmsley Creek	3%	3%	0%	27%	34%
142	176	North Bosque River Section 15 (Lake Waco)	15%	5%	2%	11%	33%
143	135	Lower Table Rock Creek	18%	1%	0%	13%	32%
144	68	Armstrong Creek Section 1 (Dry Fork and Sand Branch)	5%	5%	0%	22%	32%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
145	53	Leon River Section 1 (Lick Branch)	3%	2%	0%	26%	31%
146	61	Sabana River Section 1 (Elm, Greer, and Hunting Shirt Creek)	3%	3%	0%	24%	29%
147	86	Lower Resley Creek	4%	3%	0%	22%	29%
148	75	Walnut Creek	1%	1%	0%	26%	29%
149	67	Cow Creek	4%	3%	0%	22%	29%
150	141	Cowhouse Creek Section 9 (Bull Run and Riggs Run; Wolf Creek; Stephenson Branch)	28%	0%	0%	0%	28%
151	62	Sabana River Section 2 (Currycomb and Shinoak Branch)	3%	2%	0%	23%	28%
152	145	Lower South Fork North Bosque River	2%	2%	0%	22%	26%
153	111	Stampede Creek	8%	6%	2%	10%	26%
154	58	Flat Creek	3%	2%	0%	21%	26%
155	76	Indian Creek	2%	1%	0%	22%	25%
156	139	Cowhouse Creek Section 8 (Stampede and Hargrove Creek)	25%	0%	0%	0%	25%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
157	56	Hog Creek	4%	3%	0%	18%	25%
158	149	North Bosque River Section 4 (Sims Creek)	6%	5%	0%	15%	25%
159	147	North Bosque River Section 2 (Indian Creek)	3%	3%	0%	19%	25%
160	183	Middle Bosque River Section 3 (Wasp and Tonk Creek)	4%	4%	1%	15%	24%
161	121	Cowhouse Creek Section 1 (School Land Creek and Babtist Branch)	2%	1%	0%	21%	24%
162	51	North Fork Leon River	2%	1%	0%	21%	24%
163	70	Upper Copperas Creek	3%	2%	0%	18%	24%
164	148	North Bosque River Section 3 (Alarm Creek)	2%	2%	0%	19%	23%
165	146	North Bosque River Section 1 (Dry and Pole Hollow Branch)	5%	3%	0%	15%	22%
166	57	Leon River Section 3 (Salt, Rough, and Ellison Spring Branch)	1%	1%	0%	20%	22%
167	66	Hackberry and Henning Creek	7%	6%	0%	8%	21%
168	144	Upper South Fork North Bosque River	3%	3%	0%	14%	21%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
169	138	Lower House Creek	19%	1%	1%	0%	20%
170	137	Upper House Creek	13%	4%	3%	0%	20%
171	120	Upper Cowhouse Creek	1%	1%	0%	18%	20%
172	113	Cedar Creek (Lake Belton)	11%	6%	1%	1%	19%
173	48	Upper South Fork Leon River	2%	1%	0%	15%	18%
174	73	Duncan Creek	2%	2%	0%	13%	18%
175	60	Upper Sabana River (Yellow and Long Branch)	3%	2%	0%	12%	17%
176	78	Leon River Section 6 (Mustang and Baggett Creek)	1%	1%	0%	14%	16%
177	85	Upper Resley Creek	3%	2%	0%	10%	16%
178	55	Nash Creek	1%	1%	0%	12%	15%
179	69	Leon River Section 5 (Proctor Lake)	3%	2%	0%	9%	13%
180	71	South Copperas Creek	3%	2%	0%	6%	11%

Table A-4, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total Juniper Cover[2]	Percent Juniper on Slopes < 15% and on Tracts > 20 ha[3]	Percent Total Juniper > 30% Density on Tracts > 20 ha[4]	Percent Ownership Tracts > 202 ha[5]	Overall Ranking Factor Percent[6]
181	143	North Fork North Bosque River	2%	1%	0%	8%	11%
182	151	Upper Green Creek	3%	2%	0%	5%	10%
183	59	Leon River Section 4	1%	1%	0%	7%	10%
184	63	Sabana River Section 3	2%	1%	0%	6%	9%
185	74	Copperas Creek Section 1 (Martins Creek)	1%	1%	0%	7%	9%
186	64	Sabana River Section 4 (Turkey Creek)	1%	1%	0%	6%	8%
187	47	Dead Horse Creek	1%	1%	0%	3%	6%
188	115	Upper South Nolan Creek	5%	1%	0%	0%	6%

[1]ID = Identification.

[2]Ranking Factor 1 = Percentage of total juniper within the sub-watershed.

[3]Ranking Factor 2 = Percentage of juniper in the sub-watershed on slopes < 15% and on Farm Service Agency (FSA) tracts > 20 hectares (50 acres).

[4]Ranking Factor 3 = Percentage of total juniper in the sub-watershed within FSA tracts > 20 hectares (50 acres) that is at a density of > 30% on individual tracts.

[5]Ranking Factor 4 = Percent of the sub-watershed area with ownership tracts greater than 202 hectares (500 acres).

[6]Sum of Ranking Factors 1, 2, 3, and 4.

Table A-5. Priority rank of 188 sub-watersheds for a golden-cheeked warbler habitat restoration program based on four ranking factors.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
1	35	Lampasas River Section 8 (Sycamore, Gann, and Bennett Branch)	53%	42%	38.1%	59%	159%
2	168	Spring Creek	40%	38%	32.8%	54%	132%
3	37	Rocky Creek	41%	32%	28.4%	53%	126%
4	166	North Bosque River Section 11 (Dyes and Stanifer Branch; Shumacher Creek)	32%	32%	29.6%	49%	116%
5	38	Lampasas River Section 9 (Stillman Valley Creek)	34%	25%	21.3%	56%	115%
6	173	Neils Creek Section 2 (Turkey and Shoal Creek)	37%	34%	27.9%	39%	111%
7	31	Lower Rocky Creek	11%	10%	9.5%	86%	107%
8	172	Neils Creek Section 1 (Boggy and Jack Branch; Gary Creek)	33%	32%	27.4%	39%	106%
9	171	Upper Neils Creek (Middle Fork Neils and South Fork Neils Creek)	33%	29%	25.3%	42%	105%
10	107	Lower Coryell Creek	32%	31%	23.8%	40%	100%
11	169	Meridian Creek Section 1 (Bee Creek)	32%	31%	25.4%	38%	100%
12	165	North Bosque River Section 10 (Gibson Branch; Bosque County Reservoir)	27%	26%	22.2%	47%	99%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
13	174	North Bosque River Section 13 (Rock Springs Creek)	28%	27%	22.9%	42%	97%
14	29	North Rocky Creek	7%	7%	5.9%	84%	97%
15	164	Lower East Bosque River (Mustang Creek)	16%	10%	7.6%	70%	95%
16	23	East Fork Sulphur and Pillar Bluff Creek	2%	2%	0.9%	90%	93%
17	170	North Bosque River Section 12	29%	26%	22.3%	38%	93%
18	106	Upper Coryell Creek	33%	32%	27.0%	27%	93%
19	163	Upper East Bosque River	10%	4%	3.3%	79%	92%
20	89	Bear Creek	10%	10%	9.2%	70%	91%
21	36	Reese Creek	30%	9%	8.5%	51%	91%
22	14	Upper School Creek	15%	14%	10.2%	64%	91%
23	9	Turkey Creek	3%	3%	2.6%	80%	86%
24	34	Mill Creek	13%	12%	10.6%	62%	86%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
25	43	Salado Creek Section 1 (Rumsey Creek and Pecan Springs Branch)	13%	12%	10.2%	62%	86%
26	32	Lampasas River Section 7 (Burnet and Panther Den Branch)	24%	23%	15.8%	42%	85%
27	136	Cowhouse Creek Section 7 (Two Year Old Creek)	26%	4%	4.2%	54%	85%
28	15	Lower School Creek	12%	12%	9.4%	61%	85%
29	26	Upper Mesquite Creek	8%	8%	6.6%	69%	84%
30	126	Cowhouse Creek Section 4 (Dry and Langford Branch)	12%	12%	10.5%	60%	84%
31	167	Upper Meridian Creek (North Prong Meridian, South Prong Meridian, and Mustang Cr	23%	22%	15.6%	38%	82%
32	20	Lower Lucy and Road Hollow Creek	12%	8%	5.0%	63%	81%
33	92	Leon River Section 10 (Gum Branch; Indian, Little Egg, and Egg Creek)	14%	14%	11.3%	51%	80%
34	18	Upper Lucy Creek	8%	8%	6.1%	63%	78%
35	96	Leon River Section 13 (Eagle Creek)	16%	15%	11.5%	48%	77%
36	39	Lampasas River Section 10 (Rock, Onion, and Trimmier Creek; Upper Stillhouse Hollow	25%	19%	14.8%	34%	77%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
37	8	Lampasas River Section 3 (Heatley and Freeman Branch)	16%	15%	9.8%	50%	76%
38	24	Sulphur Creek Section 1 (Mcnett, Cemetery, and Burleson Creek)	7%	7%	4.8%	63%	75%
39	7	Upper Simms Creek	15%	14%	11.4%	46%	74%
40	117	North Nolan Creek	45%	2%	0.6%	27%	73%
41	41	Upper Salado Creek	19%	19%	12.4%	41%	73%
42	27	Lower Mesquite Creek	15%	15%	11.9%	43%	72%
43	110	Leon River Section 19 (Upper Lake Belton)	25%	23%	16.6%	28%	71%
44	80	Upper South Leon River	13%	12%	10.6%	46%	71%
45	91	Leon River Section 9 (Pecan Creek and Alex Branch)	13%	13%	8.5%	45%	70%
46	104	Henson Creek	42%	1%	0.3%	27%	69%
47	105	Leon River Section 18	21%	19%	13.7%	32%	68%
48	22	Donalson and Hughes Creek	3%	3%	2.1%	63%	68%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
49	162	North Bosque River Section 9 (Walker, Boyd, and Hester Branch)	12%	12%	10.1%	44%	67%
50	11	Lower Simms Creek	9%	9%	6.4%	50%	66%
51	112	Owl Creek	45%	5%	2.2%	17%	65%
52	12	Lampasas River Section 4 (Mill Branch)	3%	2%	0.5%	61%	65%
53	180	Upper Middle Bosque River (Cave Creek)	19%	19%	13.9%	29%	64%
54	158	North Bosque River Section 8 (Bailey Branch and Fall Creek)	13%	12%	8.0%	41%	64%
55	19	Little Lucy Creek	7%	7%	5.8%	51%	63%
56	30	South Rocky Creek	5%	5%	2.5%	56%	63%
57	109	Station Creek	9%	8%	5.8%	48%	62%
58	114	Leon River Section 20 (Bull Branch; Lower Lake Belton)	40%	7%	4.8%	15%	62%
59	44	Salado Creek Section 2 (Buttermilk and Mustang Creek; Watkins Branch)	3%	2%	0.4%	57%	61%
60	16	Fall Creek	5%	5%	2.3%	52%	60%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
61	17	Lampasas River Section 5 (Bear and Burleson Branch)	3%	3%	2.3%	54%	60%
62	132	Lower Bee House Creek	9%	9%	5.0%	44%	60%
63	127	Cowhouse Creek Section 5 (Bee Creek)	11%	10%	7.9%	40%	60%
64	108	Pew Branch	17%	15%	11.2%	29%	58%
65	181	Middle Bosque River Section 1 (Rainey Creek)	18%	16%	12.2%	22%	57%
66	3	Lower Bennett Creek	4%	3%	2.8%	50%	56%
67	175	North Bosque River Section 14 (Long Branch)	3%	2%	0.8%	52%	56%
68	129	North Bee House Creek	12%	12%	5.8%	37%	55%
69	6	North Simms Creek	6%	6%	2.9%	45%	54%
70	88	Warren Creek	5%	5%	3.6%	44%	54%
71	81	Mountain Creek	3%	3%	2.3%	48%	54%
72	40	Lampasas River Section 11 (Lower Stillhouse Hollow Lake)	27%	14%	8.2%	15%	52%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
73	95	Leon River Section 12 (Wallace, Orman, and Manning Creek; Beck Branch)	7%	7%	4.0%	41%	52%
74	161	Lower Duffau Creek	9%	9%	5.8%	36%	51%
75	128	Cowhouse Creek Section 6 (Riley Branch)	12%	10%	5.6%	33%	51%
76	125	Cowhouse Creek Section 3 (Henderson Creek)	5%	5%	2.5%	43%	51%
77	28	Binnion and Taylor Creek	13%	9%	4.2%	33%	51%
78	177	Upper Hog Creek	10%	10%	4.4%	36%	51%
79	79	Mercer Creek	0%	0%	0.0%	50%	50%
80	4	Upper Lampasas River	0%	0%	0.0%	50%	50%
81	33	Clear Creek	17%	10%	8.6%	23%	49%
82	90	Mesquite Creek	6%	6%	4.0%	37%	48%
83	65	Upper Armstron Creek (East Fork Armstrong Creek)	0%	0%	0.0%	48%	48%
84	101	Leon River Section 15 (Blue and Fourmile Branch)	7%	7%	5.5%	34%	48%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
85	13	Barkley Creek	9%	9%	4.7%	31%	47%
86	150	North Bosque River Section 5 (Liveoak Creek)	0%	0%	0.0%	46%	46%
87	154	North Bosque River Section 6 (Round Hole Branch and Spring Creek)	2%	2%	0.9%	43%	46%
88	131	South Bee House Creek	5%	5%	1.3%	39%	46%
89	42	South Salado Creek	9%	9%	4.9%	30%	44%
90	178	Hog Creek Section 1 (Live Oak Creek)	13%	12%	7.0%	23%	44%
91	5	Lampasas River Section 2 (Dry Branch)	2%	2%	0.5%	41%	44%
92	116	Lower South Nolan Creek	16%	8%	3.3%	23%	43%
93	153	Green Creek Section 1 (Cottonwood Creek and Heavenly Branch)	2%	2%	1.9%	38%	43%
94	155	Gilmore Creek	5%	5%	3.9%	32%	42%
95	84	Leon River Section 8 (Chappell Creek and Bee Branch)	1%	1%	0.4%	40%	42%
96	142	Cowhouse Creek Section 10 (Oak Branch; Lake Belton)	42%	0%	0.0%	0%	42%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
97	185	Upper South Bosque River (Willow Creek)	0%	0%	0.0%	41%	41%
98	49	Middle Fork Leon River	0%	0%	0.0%	41%	41%
99	152	Little Green Creek	0%	0%	0.0%	40%	40%
100	25	Sulphur Creek Section 2 (Gibson, Gooch, Pecan, and Denson Branch)	8%	5%	2.3%	29%	39%
101	186	Harris Creek	0%	0%	0.0%	39%	39%
102	103	Leon River Section 17 (Cottonwood, Shoal, and Turnover Creek)	19%	9%	5.3%	11%	37%
103	2	South Bennett Creek	1%	1%	0.6%	36%	37%
104	123	Partridge Creek	0%	0%	0.0%	37%	37%
105	54	Leon River Section 2 (Jim Neal Branch)	0%	0%	0.0%	37%	37%
106	72	Sweetwater Creek	4%	4%	2.1%	30%	37%
107	99	Upper Plum Creek	1%	1%	0.0%	36%	37%
108	21	Lampasas River Section 6	3%	3%	0.9%	32%	36%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
109	122	Gholson Creek	0%	0%	0.0%	36%	36%
110	10	Patterson Creek	1%	1%	0.5%	35%	36%
111	130	Bee House Creek Section 1 (Cromeans and Roberts Creek; Patterson Branch)	3%	3%	1.5%	31%	36%
112	94	Leon River Section 11 (Alexander and Sycamore Creek)	5%	5%	1.7%	29%	36%
113	133	Table Rock Creek	2%	2%	0.6%	33%	35%
114	134	Settlement Branch	6%	6%	2.3%	26%	35%
115	93	Pecan Creek	9%	8%	4.1%	21%	35%
116	140	Browns Creek	34%	0%	0.0%	0%	34%
117	1	North Bennett Creek	0%	0%	0.0%	34%	34%
118	100	Lower Plum Creek	5%	5%	3.3%	25%	33%
119	50	Lower South Fork Leon River	0%	0%	0.0%	33%	33%
120	83	Leon River Section 7 (Joplin and Mills Creek)	0%	0%	0.0%	31%	31%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
121	82	South Leon River Section 1 (Live Oak and Walnut Creek)	0%	0%	0.0%	31%	31%
122	52	Colony Creek	5%	5%	2.1%	23%	30%
123	182	Middle Bosque River Section 2 (Bluff Creek)	9%	9%	4.8%	15%	30%
124	157	Honey Creek	4%	4%	2.0%	23%	29%
125	87	Rocky Creek	0%	0%	0.0%	29%	29%
126	124	Cowhouse Creek Section 2 (Little Cowhouse Creek)	1%	1%	0.0%	28%	29%
127	102	Leon River Section 16 (Dodd and Stillhouse Branch)	8%	7%	4.9%	14%	27%
128	77	Holmsley Creek	0%	0%	0.0%	27%	27%
129	184	Middle Bosque River Section 4 (Pecan Creek; Lake Waco)	1%	1%	0.0%	26%	27%
130	53	Leon River Section 1 (Lick Branch)	1%	1%	0.2%	26%	27%
131	187	South Bosque River Section 1 (Cloice Creek)	7%	6%	3.7%	16%	26%
132	75	Walnut Creek	0%	0%	0.0%	26%	26%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
133	97	Leon River Section 14	6%	6%	2.3%	16%	26%
134	156	North Bosque River Section 7 (Grubbs Branch)	2%	2%	0.5%	22%	25%
135	61	Sabana River Section 1 (Elm, Greer, and Hunting Shirt Creek)	0%	0%	0.0%	24%	24%
136	62	Sabana River Section 2 (Currycomb and Shinoak Branch)	0%	0%	0.0%	23%	23%
137	86	Lower Resley Creek	0%	0%	0.0%	22%	22%
138	68	Armstrong Creek Section 1 (Dry Fork and Sand Branch)	0%	0%	0.0%	22%	22%
139	67	Cow Creek	0%	0%	0.0%	22%	22%
140	76	Indian Creek	0%	0%	0.0%	22%	22%
141	145	Lower South Fork North Bosque River	0%	0%	0.0%	22%	22%
142	119	Leon River Section 21 (Pepper and Bird Creek)	4%	2%	2.0%	15%	21%
143	188	Lower Bosque River (Lake Waco)	2%	0%	0.0%	19%	21%
144	51	North Fork Leon River	0%	0%	0.0%	21%	21%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
145	58	Flat Creek	0%	0%	0.0%	21%	21%
146	121	Cowhouse Creek Section 1 (School Land Creek and Babtist Branch)	0%	0%	0.0%	21%	21%
147	135	Lower Table Rock Creek	7%	0%	0.0%	13%	20%
148	57	Leon River Section 3 (Salt, Rough, and Ellison Spring Branch)	0%	0%	0.0%	20%	20%
149	179	Hog Creek Section 2 (Lake Waco)	2%	2%	0.5%	17%	19%
150	46	Lampasas River Section 12 (Mitchell Branch)	7%	5%	2.5%	9%	19%
151	183	Middle Bosque River Section 3 (Wasp and Tonk Creek)	3%	2%	1.3%	15%	19%
152	147	North Bosque River Section 2 (Indian Creek)	0%	0%	0.0%	19%	19%
153	148	North Bosque River Section 3 (Alarm Creek)	0%	0%	0.0%	19%	19%
154	141	Cowhouse Creek Section 9 (Bull Run and Riggs Run; Wolf Creek; Stephenson Branch)	19%	0%	0.0%	0%	19%
155	159	Upper Duffau Creek	2%	2%	0.3%	16%	19%
156	70	Upper Copperas Creek	0%	0%	0.0%	18%	18%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
157	56	Hog Creek	0%	0%	0.0%	18%	18%
158	120	Upper Cowhouse Creek	0%	0%	0.0%	18%	18%
159	139	Cowhouse Creek Section 8 (Stampede and Hargrove Creek)	17%	0%	0.0%	0%	17%
160	48	Upper South Fork Leon River	0%	0%	0.0%	15%	15%
161	146	North Bosque River Section 1 (Dry and Pole Hollow Branch)	0%	0%	0.0%	15%	15%
162	149	North Bosque River Section 4 (Sims Creek)	0%	0%	0.0%	15%	15%
163	118	Lower Nolan Creek	11%	9%	2.6%	1%	14%
164	78	Leon River Section 6 (Mustang and Baggett Creek)	0%	0%	0.0%	14%	14%
165	144	Upper South Fork North Bosque River	0%	0%	0.0%	14%	14%
166	98	Mustang Creek	1%	1%	0.0%	13%	14%
167	73	Duncan Creek	0%	0%	0.0%	13%	13%
168	160	Little Duffau Creek	4%	4%	2.5%	6%	13%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
169	60	Upper Sabana River (Yellow and Long Branch)	1%	0%	0.0%	12%	13%
170	176	North Bosque River Section 15 (Lake Waco)	1%	1%	0.0%	11%	12%
171	55	Nash Creek	0%	0%	0.0%	12%	12%
172	45	Salado Creek Section 3 (Smith, Holland, and Moon Branch)	1%	1%	0.2%	10%	11%
173	111	Stampede Creek	1%	1%	0.0%	10%	11%
174	85	Upper Resley Creek	0%	0%	0.0%	10%	10%
175	69	Leon River Section 5 (Proctor Lake)	0%	0%	0.0%	9%	9%
176	138	Lower House Creek	8%	1%	0.5%	0%	8%
177	66	Hackberry and Henning Creek	0%	0%	0.0%	8%	8%
178	143	North Fork North Bosque River	0%	0%	0.0%	8%	8%
179	59	Leon River Section 4	0%	0%	0.0%	7%	7%
180	74	Copperas Creek Section 1 (Martins Creek)	0%	0%	0.0%	7%	7%

Table A-5, cont.

Priority Rank	Map ID[1] No.	Sub-Watershed Name	Percent Total GCW[2] Habitat[3]	Percent Total GCW[2] Habitat on Private Land[4]	Percent GCW[2] Habitat on Private Lands in Large Management Units[5]	Percent Ownership Tracts > 202 ha[6]	Overall Ranking Factor Percent[7]
181	71	South Copperas Creek	0%	0%	0.0%	6%	6%
182	113	Cedar Creek (Lake Belton)	5%	1%	0.4%	1%	6%
183	63	Sabana River Section 3	0%	0%	0.0%	6%	6%
184	64	Sabana River Section 4 (Turkey Creek)	0%	0%	0.0%	6%	6%
185	151	Upper Green Creek	0%	0%	0.0%	5%	5%
186	137	Upper House Creek	3%	1%	0.2%	0%	3%
187	47	Dead Horse Creek	0%	0%	0.0%	3%	3%
188	115	Upper South Nolan Creek	2%	0%	0.0%	0%	2%

[1]ID = Identification.

[2]GCW = golden-cheeked warbler.

[3]Ranking Factor 1 = Percent of sub-watershed with moderate and high potential GCW habitat.

[4]Ranking Factor 2 = Percent of sub-watershed with moderate and high potential GCW habitat on Farm Service Agency (FSA) tracts.

[5]Ranking Factor 3 = Percent of sub-watershed with > 16 ha (40 ac) of high potential GCW habitat or > 32 ha (80 ac) of moderate potential GCW habitat within an individual FSA tract.

[6]Ranking Factor 4 = Percent of the sub-watershed area with ownership tracts greater than 202 hectares (500 acres).

[7]Sum of Ranking Factors 1, 2, 3, and 4.

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  Project Engineer, July 2005 – Present
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  Research Assistant, January 2003 – June 2005
- HDR Engineering, Austin, Texas
  Project Engineer, January 2000 – December 2002
- Agro Engineering, Alamosa, Colorado
  Engineer Intern, May 1999 – August 1999
- Texas A&M University Farm Operations, College Station, Texas
  Student Technician, April 1997 – May 1999
- Case Corporation, Maple Park, Illinois
  Engineer Intern, June 1998 – August 1998
- Austin Surveyors, Austin, Texas
  Assistant Surveyor, May 1996 – August 1996

Professional Memberships:

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- American Water Works Association
- American Society of Agricultural Engineers